School Science

Vol. IV.] MAY, 1904. [No. 2

SHOULD THE STUDENT BE DIRECTED TO EMPHASIZE ONE POINT ONLY IN EACH EXPERIMENT, OR SHOULD HE BE HELD RESPONSIBLE FOR ALL NATURALLY RELATED PHENOMENA?*

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The question as worded seems to be a little uncertain of interpretation, and therefore a word of introduction on this point may help in an understanding of the discussion. The first part seems to imply that all the phenomena of an experiment should be considered by the pupil, but that he should be led by careful direction to see and emphasize one main point and try to bring all the phenomena observed to bear upon this. Phenomena which do not contribute to the main problem may either be neglected altogether or regarded only as incidental. Whether the student observes such phenomena at all or not, in any case he should not be held responsible for a full investigation or explanation of them, and possibly no explanation at all. This would seem a fair interpretation of the expression, "Emphasize one point only in each experiment."

In the last part of the question the expression, "All naturally related phenomena," would leave much to individual judgment in its application. Taken in its broadest sense, it ought to include all of the phenomena of an experiment, since all phenomena of nature are more or less closely related to all other phenomena. We find it difficult indeed to find any line of separation between chemistry and physics or between chemistry and other sciences. All belong to the field of the material world and are naturally more or less related to each other. It would seem to me exceedingly

* Read before the Central Association of Science and Mathematics Teachers, Chemistry Section, November 27, 1904.

difficult to lay down any general principle or rule by which one could decide which phenomena were and which were not naturally related. Probably in practice each teacher would decide for himself in the matter and no doubt there would be wide difference as to what students should be held responsible for in case all could agree in favor of the last part of our question. I think no one would go so far as to think it wise to eliminate entirely all but one main point from an experiment. Not only would this be unwise, but it would be a psychological impossibility. Even if a student were to try to follow such a direction it would be impossible for him to give exclusive attention to one point only. Furthermore, it is undoubtedly apparent to all that the one main point should not be considered in isolation, but in its relationships. Only then could it be made to contribute to the knowledge of the student.

Then again there is, in practice at least, a wide difference of opinion as to what properly constitutes a laboratory experiment. Some appear to consider it as the simplest form of manipulation; as, for example, testing the action of hydrochloric acid on zinc. Others would regard this simply as part of a larger unit of study, which might come under the heading, "A Study of Hydrochloric Acid," or "A Study of Hydrogen." Manuals illustrating both of these ideas, especially the former, are familiar to all chemistry teachers.

Perhaps a little fuller statement of the question may help to remove these difficulties and bring us onto a common ground of discussion. If I interpret aright the thought in the mind of the committee which selected the question, it might be put as follows: "Should each laboratory experiment be so planned by the instructor that it will illustrate one main point, and the student held responsible for an investigation and explanation of those phenomena only which bear directly upon this main question, or shall he be expected to investigate and find an explanation for all phenomena in any way related, as fully and as minutely as possible within the limits of apparatus and skill of manipulation?"

An illustration or two will serve to make this view of the question clearer.

In the preparation and study of oxygen is it better to focus the student's attention upon the one point of becoming acquainted with this substance, by finding out its properties and chemical conduct, putting little emphasis upon such incidental phenomena as the changes in the potassium chlorate, the character of the product left and the part taken by the manganese dioxide, or should the pupil be held responsible for an investigation and explanation of all of these, and then perhaps be required to determine also how much oxygen can be liberated from a known weight of potassium chlorate?

To take a second case, in burning phosphorus under a bell jar of air, is it enough for the student to find out that phosphorus in burning has removed something from the air and formed a solid product soluble in water, or should he be held responsible also for a full and complete study of phosphorous pentoxide, phosphoric acid, etc., and then determine also the relative weights of the reacting substances, as has been advocated by some?

The position here taken regarding this question is that beginning students are not able to become investigators of all the phenomena and problems growing out of the relationships of an experiment, and even if able it would not conduce to the highest value of the subject or to the greatest interest in the study to have them undertake such a task. The pupil needs to have clearly set before him some particular object or purpose in each experiment which shall serve as a center about which he may organize the many details, and by which he may judge of the relative importance of all the phenomena observed. There is great danger, as it seems to me, of spreading a beginning pupil over so wide a field of unexplored thought that he becomes bewildered and confused and finds himself unable to organize the results of his experiment into any clear or definite knowledge, and thus fails to get the most valuable training which the subject can provide.

It is generally conceded, I believe, and especially by chemistry teachers, that the subject of chemistry is capable of providing a most valuable discipline, as well as much very practical information, which is closely related to every-day life. A brief consideration of some of these values may help to establish a basis for a larger view of this question.

Along the disciplinary side, chemistry gives an excellent and a unique training of what may be called the apperceptive observation; it cultivates the scientific imagination, develops the logical reasoning power, trains the powers of comparison, discrimination and judgment, and tends toward the formation of a scientific habit of mind, that habit which refers opinions and theories to creditable evidence, and bases the conclusions of life on well-authenticated facts. The discipline along some of these lines is gained, it is believed, to a larger degree in the study of chemistry than in almost any other science study, because the exact phenomena of the subject are not usually on the surface of things, but lie more or less hidden from direct observation.

The valuable information of the subject, which is closely related to many of the common processes and phenomena of domestic and industrial life, needs hardly to be referred to, especially among chemistry teachers. The many phases of hygiene, agriculture, domestic economy, industrial processes, etc., which involve some chemical activity or depend upon some chemical principles, will come at once to the minds of those at all familiar with these studies.

Now, these benefits come to the mature mind in largest degree through a treatment of the subject as a science, although it might, perhaps, be conceded that a sort of nature study treatment is adapted to grade work. It would seem as if all would agree to this, and yet from the treatment of the subject which one frequently finds in the secondary schools it might be judged otherwise.

If, then, the subject should be treated as a science in the secondary schools, and I shall assume in this discussion that it should, it will be pertinent to inquire, first, what a science involves, and, second, what part does the laboratory work play in the teaching of the science and how can it be made to contribute most to such a development of the subject.

To turn our thought to the first point, a science involves, first, a general or central proposition, which lies at the basis of all the facts and phenomena of the subject.

Second, it involves further a body of facts and data capable of verification by observation or experiment.

Third, it involves the possibility of a systematic and logical arrangement of the data by comparison, differentiation and classification.

Fourth, it involves the establishment of certain generalizations, or fundamental principles, which are definitely related to each other and to which all data may be referred and by which all phenomena may be explained.

Fifth, and lastly, it involves the application of these general principles to all new phenomena or facts of the subject.

Measured by these propositions, it would readily be admitted that chemistry is a science, although, perhaps, not yet perfectly developed. It may, indeed, have to suffer considerable modification in the future, as it has in the past. Chemistry should then be capable of some logical order of presentation, which order would be essential to the proper development of the subject, at least in general outline, if not in all particulars.

Turning now to the second question suggested above, what is the function of the laboratory work in the study of this science, or, to be a little more definite, what are the values or aims of the laboratory work in general, and what should be the aim of each experiment?

It would seem to me at the outset that it is not the main purpose of the laboratory to furnish information to the student, although it will undoubtedly do that to quite an extent. However, information could be gained more easily and more quickly from other sources.

The laboratory should provide valuable training, especially along the lines of what has been referred to as apperceptive observation and scientific imagination. Reasoning, judgment and generalization will be trained to some degree, but a better opportunity for the training of these is offered in the book and class-room work, where the knowledge from all sources should be organized, generalizations made and general principles established.

But where the laboratory work seems most indispensable to me is in providing the student with an experience, or, as some psychologists would call it, an apperceptive mass, which is rich and distinct in consciousness and to which all class-room and book work

may be referred and related, and with which these may be assimilated for the formation of vivid and definite concepts.

This apperceptive mass or experience can come only through the use of the perceptive faculties, or, as we commonly say, the senses. This is where observation comes in for its fullest exercise. It is just as impossible to build up this rich and clear knowledge of chemical substances and phenomena without the laboratory work as it is to give a child who has never seen a steam engine a clear imagination image of that machine by simply describing one to him, or to give him a vivid knowledge of the city of Chicago by telling him about it. Both these are psychologically impossible, unless the child has had some experience about machines and in large cities from which he can construct the new image.

If, then, the laboratory has for one of its most important purposes the constructing in the pupil's mind an experience upon which the book and class-room work can be developed, and if the best results are attained by treating the subject as a science, then it would seem, since the science must proceed in a definite and logical order, that at any stage of the work there are certain points which are relatively important and indeed essential, and others which are only incidental and relatively unimportant at that stage, though at a later stage they might be essential. For this reason it would often seem a wise thing to introduce an experiment a second time for further study of points at first incidental but now essential.

Furthermore, in leading pupils to build up the laboratory experience there is, it seems to me, a grave danger that the teacher, with his fuller experience and understanding of the subject, will overreach the capacity of mind of the pupil in his requirements. Teachers often fail to realize how many steps must be taken before new knowledge can come into full possession of the pupil. Sensations must be organized into percepts; out of percepts, memories, etc., must be constructed what we have referred to as an apperceptive mass, or experience, and finally a vivid concept must be formed by association, comparison, discrimination and abstraction. Nor is this all. As Professor James has pointed out in his "Talks to Teachers," every new impression

or reaction demands some form of outward expression, which gives to the mind the consciousness of having reacted. This would seem to mean, when applied to laboratory work, that every impression should be referred outward again to the phenomena of the experiment for confirmation and adjustment before it becomes perfectly clear to consciousness. Here lies much of the value of many questions in the laboratory directions and the benefit of carefully written notes on each experiment. These call for this outward reference constantly during the progress of the experiment.

From these considerations it appears that a large amount of mental effort is necessary in apprehending and interpreting the phenomena of a perfectly new experiment. Teachers of chemistry, and it applies to others as well, often fail to realize how limited is the capacity of the mind in this regard, and it is of the utmost importance that this limit should not be overreached in the laboratory work.

All this applies with especial emphasis to chemistry, for this subject offers greater newness and strangeness to the average pupil than almost any other science study. It has been well pointed out by Professor Smith that the phenomena of physics are much more "obvious to the senses than those of chemistry," and further that physics derives "more abundant material for illustration and application from the experiences of every-day life" than chemistry.

Another point often lost sight of is that the nomenclature of the subject and the means of expressing chemical facts are almost wholly new to the pupil. I have become convinced that much of the confusion which so often arises in a beginning course in chemistry comes from the fact that the terms and symbols used in the subject are so unfamiliar that the pupils find difficulty in using them as a medium of thought. They are exactly in the condition of some of us when we try to think in some foreign tongue, or of the first grader who is trying to master the symbols of written language. Why is it that pupils become confused and often completely bewildered in trying to think out chemical problems which involve very simple mathematical conceptions? It is often charged to poor mathematical training, but I feel sure

that this is wrong in the majority of cases. It is because the medium of thought, or, as we may call it, the language of chemistry, is not familiar enough so that the student can think in such symbols. As an illustration take the problem: How much hydrogen by weight can be formed by the action of hydrochloric acid on five grams of pure zinc if one atom of zinc liberates two atoms of hydrogen? How often have chemistry teachers seen pupils in confusion in trying to understand the solution of such a problem! Yet how quickly the same student will extricate himself if we change it to the following, which involves exactly the same mathematical relations: How many bushels of potatoes can be bought for $10 if four bushels are worth $2?

We have but to look back to chemical history to recall that the most skilled students were hopelessly mixed in their use of the terms atom and molecule for half a century or more, and the so-called "new chemistry" came only with a fuller understanding of these terms.

It must be apparent without further discussion that the field of chemistry presents an unusual number of complex and intricate phenomena which are very unfamiliar to the beginning student, and also calls for the use of a large number of new and unfamiliar symbols and terms.

Under these conditions there is danger of expecting students to observe and interpret too many phenomena and investigate too many intricate questions in the same experiment, which is likely to result in confusion and dislike for the subject. What the student needs is directions which will help him to seize upon the important point of the experiment and in the light of this to sift properly the other phenomena. Even with wise directions and all our efforts to simplify the presentation he will find many difficulties at best and need much direction and questioning while the experiment is in progress.

The application and import of an illustration or two will be apparent. Everyone at all acquainted with children has witnessed the bewilderment of a young child when he is first taken to a circus or fair, where there is a great profusion of new things which he is not able to link to his former experiences.

One feels something of the same bewilderment when he finds himself for the first time in a great city like Chicago.

Would it not be quite as unreasonable to hold a beginning student in chemistry responsible for all "naturally related phenomena" in an experiment as it would be to hold a six-year-old responsible for a full description and explanation of all naturally related impressions which came to his consciousness during a day's visit on midway or at the St. Louis Exposition? In the latter case the child would meet our expectations just about as our students of chemistry often do, and the reason in the latter case is much like that in the former.

Are we not, in our ardent zeal for thoroughness and for cultivating the spirit of investigation in our students, in danger of becoming as ridiculous as some of our "Correlation" friends who begin with a class of children to study a peanut and end somewhere with the mighty conceptions of the universal brotherhood of man and the fatherhood of God?

It would seem to have been an appreciation of these ideas which led the renowned Faraday to insist when shown the experiments of other scientific men, upon knowing first exactly what to look for, so that his whole attention might be rightly directed to the precise matter in hand.

And it is at once apparent that the skilled investigator is immeasurably better able to differentiate quickly the essential and important phenomena and bring them to bear upon any question in hand, than the beginning student. The former has a large and rich experience which enables him to see at a glance the significance and relative importance of phenomena which would be as opaque as midnight to the latter. Even in the case of the investigator we have only to look to history to see the confusion and error which resulted from the inability of even the trained mind to properly differentiate and interpret the many phenomena which crowded before the vision simultaneously. One can not but be struck with this fact in reading the original papers of most of the early investigators.

These considerations seem to me to make it very desirable that the pupil should be led to center his thoughts in each experiment

upon a clear and definite problem, upon which all phenomena should be brought to bear as far as possible and that all phenomena which can not contribute to this main point should be regarded as incidental only, and of secondary importance. This main purpose should in most cases be stated for the pupil, or at least suggested to him by an appropriate heading, or by careful questions. In some cases perhaps the pupil may be led to formulate a problem for himself. Then, with a definite point before him, the student should be given some suggestions as to what are the important phenomena to be observed, and some assistance by pertinent questions in seeing the proper relationship between various phenomena and the bearing of each upon the main problem.

Besides this he will need individual questioning and suggestions to clear up confused points. Furthermore, he will need the help of text-books and reference books and the classroom discussions to help him to organize his experience and knowledge into a logical body of thought and make application to other familiar phenomena.

The development of the science will demand that each experiment should be as typical as possible of a general class of phenomena, or in other words, each experiment should provide as large an experience as possible, with which the student can associate knowledge gained from other sources.

Then these typical experiments should be so related that they make a systematic and unified whole, so as to carry, in the words of Professor Smith, "the thread of the subject" and form "the backbone of the work."

In conclusion, let us sum up the whole matter.

Chemistry is not now, as it perhaps was for a long time, a miscellaneous collection of facts, without relationship or coherence of parts, or unifying principle; but it is a science. We do not know all its mysteries. There are yet hidden treasures to be unearthed, and our theories are yet imperfect; but the subject has been placed on a firm foundation and we have a series of fundamental principles, in the light of which all phenomena may be interpreted. The highest value of the subject to the beginning pupil comes from bringing him into a knowledge and appreciation of the

development of this science; of the struggles and triumphs it has passed through; the principles and laws it has established, and the many useful applications it has furnished to advancing civilization.

In presenting this science there is a logical order which should be followed, and each laboratory experiment should furnish the experience on which can be built some step in this development. To do this the experiment must have a clear and definite purpose, which should be emphasized as the main point of the experiment, all other points being made to contribute to this main point. If they can not do this, they should be regarded as valueless, at least in this experiment.

We reach the same conclusion when we consider the difficulty with which the untrained mind comes into full possession of a new piece of knowledge. There is great danger that the teacher of any subject will overlook some of the stages in the requisite mental process and only confusion and atrophy can result from overcrowding the mind with new facts and phenomena, all of which must be explained and put into relationships.

All this applies with especial emphasis to the subject of chemistry on account of the newness of the subject to the average pupil, and also because of the hidden nature of the phenomena of the subject, and the difficulty of observing them by any direct means.

Furthermore, it should be kept in mind that the symbols and nomenclature for the expression of chemical thought, present so large a strangeness to the beginning pupil that he frequently finds himself unable to develop or to organize his thought because of the lack of a familiar medium in which to clothe it.

It has seemed to me that chemistry work has failed of its best results in many secondary schools in large part because of weakness in the laboratory work. Two weaknesses have been in opposite directions.

The first has been that of telling pupils in their laboratory directions, not only what to look for, but also what they will see, when by judicious questions they might be led to discover the facts by their own observations. This weakness is illustrated

in many laboratory manuals, and it would seem that there had often been a failure to distinguish between directing a pupil's observations and actually making them for him.

The other weakness is perhaps more directly along the line of this discussion. It is that of setting pupils to work in the laboratory aimlessly or at least without sufficient guidance and then expecting them to observe all phenomena; discriminate between essentials and non-essentials; place all in proper relationship, and draw correct inferences from all these complicated phenomena. These things all seem very plain to the teacher; but to the pupil with his limited experience and training, they are as impossible as for a fifth grader to perfectly understand the change of seasons or the astronomical theory of the glacial epoch.

A PLEA FOR STUDENT LABORATORY WORK IN A FIRST COURSE IN PHYSICS.

THIRD PAPER.

BY W. F. MONCREIFF,

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Near the end of the session last year the president of the college requested me to consider and report on the advisability of making a certain change in the method of work in physics. Desiring to base a report on as safe ground as possible, I submitted to the class, at the close of the final examination in physics, substantially (I have not the exact wording) the following questions:

1. On the basis of your own experience, compare the advantages and disadvantages of an experimental first course in physics with those of a textbook course.

2. Has your interest been mainly in passing on required work or in the subject matter? How would this have been affected if the course had been textbook work?

I asked for a frank, full and candid expression, stating that I wished it as an element for personal guidance in deciding a

question that had arisen regarding the work in physics. Response was voluntary and answers had no bearing on the examination just finished. All responded. The unanimity of opinion was surprising. To the first question only one response in a class of sixty-six favored the text. This paper is included below among those selected to represent the student view.

While I have no respect for that form of imbecility which panders to student opinion for the sake of a little cheap popularity, I strongly believe that students may have much to say on pedagogical matters, worthy of careful consideration by those responsible for the methods of the school. Surely the student side of the pedagogical problem is entitled to a hearing, and it has not yet been *over* heard. Hence I submit the papers below as written and with the consent of the writers.

It is but just to these young ladies to say that their opinions were formulated on the spot, without previous notice that they would be asked for or any intimation that they would ever appear in print and at the end of a difficult examination near the close of examination week. The purpose to print them did not then exist in my own mind. To those who know the girls the sincerity of these expressions, if it were not apparent in the context, is guaranteed by their names at the end. But for the benefit of those who do not know them it may be helpful to say that they had no knowledge of what the question being considered by me was, nor any intimation of what my personal opinion in the matter might be. Besides this, the questions submitted do not reveal or even suggest the question that was in my mind, but the answers give, indirectly, the evidence sought. The candor of these expressions is further attested by the fact that I asked at the same time that the defects of the course *as given* be pointed out and remedies suggested; and they were pointed out frankly and freely—some that I had not seen.

The average age of these girls was about 18 years, and they were Normal juniors in our four-years' course—one year from graduation. That some of the effects of the method of work would be greater in the case of these students than in the case of high school students, because of their greater maturity, is freely ad-

mitted; but the difference is one in degree, not in kind. It is the *kind* of results produced that is the chief concern in this series of papers.

"By a textbook course I would not have been acquainted first hand, but second or third hand, with the facts and principles of physics. I would not have been as deeply impressed, for it would have been only through memorizing or reading that my mind was impressed, and not through seeing and observing, which always makes things so clear to me. I believe and remember what I really see and perform. The laboratory course gave me a hand-to-hand acquaintance with physics. In dealing with it I felt that I was 'within the pale' of living reality and not on the borderland of a bookish friendship with physics. Again, if I had been given a 'textbook course,' how could I have been introduced to the method of scientific investigation? I am sure if I had studied a textbook I would not have gotten any habit of discrimination between fact and theory, for the fact and the theory would have been given me in unlabeled doses by the author of the textbook. Now, if I had studied a textbook and had no laboratory work, I do not see how I could draw or evaluate scientific conclusions. I have studied a textbook on physics before this and have found what I have said above to be true. My object and real interest in performing experiments was to see how the things would turn out, not simply to pass over so much required work. My interest in the subject matter would have been less had I taken a textbook course, for I am always more fully interested in what I myself do than I am in reading what some one else has done."

RHEA DALLAS.

"I think it would have been better to have had a textbook course. We are supposed to go to class without opening the book and there we perform the experiments or read over the text matter. The general facts and principles are not memorized, only read, and the girl is not really acquainted with them. Then, when examination comes, she has to cram all principles, laws, etc., in one night, and becomes confused from not having been required to learn while going over. I took a course in physics before coming to Winthrop and we had to recite the lesson. Experimental work was done before us, and while I found the textbook hard, still I think I derived better results, because I had to learn each thing as I went along. I think the work is made as interesting as possible by experimental work, but I would have derived more benefit by use of the textbook."

CARRIE ONSLOW.

"I think I have gotten better results through this laboratory course in physics than I should through a textbook course. I have studied physics before in a graded school where we had lessons assigned to us from the book, studied these lessons and recited them in class. I found in studying

it again that I knew very little of the general laws, although I had had a good teacher.[1] For this reason I think the laboratory course has done me more good. Before, I studied the laws of physics, never questioning their truth and with little idea as to how they were derived. After the present course in the laboratory, in which we had to derive these laws, I do not look upon every law as a fixed statement of truth. And I have a better idea as to how scientific men have gotten these laws. It has supplemented our course in chemistry, while chemistry has helped us in this course. We have gotten a better idea of science in this course. I have enjoyed the course and have been interested in it, especially when we performed experiments ourselves, as we did, except toward the end."[2]

RACHEL BRAWLEY.

"It is an admitted fact that knowledge is got through the senses and laboratory work is the best means of securing this. Pupils may apparently learn more from the book, for they may cover more ground, so to speak, but certainly they will forget it more easily than those who have actually seen the things and thought about them in writing up their notes. I think writing the experiments is an important part of the work. To think out so as to be able to give a concise statement of facts will give more knowledge than reading textbook matter. I think this has been shown to me very clearly, for in my review for examination those things about which we had read and had done very few, if any, experiments were not half so easily remembered as those about which I had done experiments. My real interest was generally in the work, but in a few places I really took interest in it to be able to pass my examination. This was true only in the case when we were studying text matter (as we did near the end at some places in 'Light'), so I would say that my interest would certainly be greater in experimental work than in textbook work."

LEILA HEPBURN.

"The scientific method of investigation consists in having the investigator find out for herself—not to depend upon theory—to learn by doing. After the facts have been obtained, the scientific investigator draws her conclusions, inferences, etc., from them and discovers the theory through the facts. By a textbook course this could not have been realized, nor could the power of discrimination, of observation, and of drawing conclusions from given facts, have been cultivated. Then, too, without an appeal to the senses our course would have been a process of cramming for daily recitation and 'exams,' and after that, without the sense foundation, we would, most likely, have forgotten everything. Also, the laboratory course gave us an association with nature and this made our ideas much broader than they would have been otherwise. The textbook will soon be for-

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[1]This teacher is one of the very strongest men in the state—evidence that the best teacher must fail if his method is, *per se*, bad. W. F. M.

[2]The text was used toward the end of the year to enable us to "get over" the subject of "Light." W. F. M.

gotten, but the impressions I got by experimenting myself will last. While my interest in the study of physics has, no doubt, been greatly aided by the hope of passing, yet the work itself has been of the greater interest. If the work had been only textbook, without those experiments on electricity, magnetism, sound, and heat, it would have been tiresome to every one. I think the laboratory course far more interesting than the textbook course and if I ever teach physics I shall do my best to use the laboratory method."

MAE DELLE BARRE.

"One always remembers what she does and sees better than what she studies from a book. You can get the real meaning of laws, etc., if you work them out experimentally by concrete examples. Without the experiment you try to memorize laws without knowing what they really mean. You can memorize them, but certainly you will soon forget them. I have been very much interested in my work in physics this year. My interest has been in the experiments performed and the things, previously unknown, learned from them. I think a course from a textbook would have been much duller and also harder to understand."

CARRIE HUNTER.

"A more detailed knowledge of the subject might be gotten from the textbook, but much valuable training would be lost. The general facts and principles can be gotten from a textbook, but they will be better remembered from the experiments. The scientific method of investigation will be more clear to one if pursued in the laboratory. She also has opportunity to see for herself where theory comes from and where it often fails. She does not have to accept the textbook blindly. She can draw her own conclusions from what she has seen herself. Things become clearer and more real. I am certainly glad for other reasons that I took physics and took it by this method."

KITTIE KIRKPATRICK.

"When experiments are performed by the pupil they become more a part of himself and remain in his memory longer. Experimental work is a form of reaction and therefore facts learned in this way are clinched in mind. Laboratory work makes us more familiar with the material world and acquaints us better with the phenomena of nature, and thus makes our life more real and natural. Knowledge learned from textbooks gives the possessor a feeling of uncertainty and unreality. He feels like he is apart from nature and stands as if he were 'without the pale.' Again, laboratory work makes us more observant of things, makes us more accurate, makes us realize the inadequacy of mere verbal description in comparison with the actual doing of the work. It makes us more honest and precise, for we must do the thing definitely right or definitely wrong, thus making it impossible for us to hide our ignorance behind ambiguous words. Again, laboratory work holds our attention and interest and hence the

impressions gained are more lasting, for we work better when we do not work because we have to. In fact, laboratory work changes our entire conception of things and gives us a different intellectual attitude."

GRACE KIRKPATRICK.

"In textbook work we have a great tendency to get the words of the book, and by giving these to the teacher make him think we understand the lessons; and, in fact, we may think we understand it. In experimenting there is no 'fooling' yourself nor the teacher, for your work is before you and is right or wrong. If wrong, you do not lose as much as when you miss a question asked in class, for you find the cause of your error, which may be a great many times more valuable to you than if you got the correct result. By studying the textbook we get only the thoughts of others, while by doing the work ourselves we get original thought. I have found that in textbook study the work is pure memory, without association with concrete facts, of course with some abstract reasoning. While in our work this year there has been no memory without the concrete facts upon which the effects and reasons were based, all closely linked. I have not thought once about passing until I began studying a few weeks ago for examination. Then I worked to pass. But is not this fact an argument in favor of experiments? For the last few lessons have been textbook work. My work, such as it is, has been done from interest in the subject."

IDA SALLY.

"It is always hard to get laws and principles fixed in the mind when there is nothing concrete about them. But in dealing with concrete things the reasons for the laws and principles can be seen and then they are fixed in the mind, whereas words might be fixed there for a little while, but they soon drop into subconsciousness. I think I would have known more about geography if I had studied real things just as I have in physics, and it would not have required so much effort in trying to remember so many different things. Although physics is one of the hardest subjects I have, that is, as a textbook course, it has been made comparatively easy by the experimental work. At first I worked only to get through, but I became interested in the work and have enjoyed it. The longer I have worked at it the more I have liked it. I am sure if the course had been a textbook course I should have hated it, for of all things I hate to do it is to try to remember hard and dry laws when I can see no reason for them. But when I can reason them out they become interesting and I can keep them tight in my mind."

SUSIE PARKER.

"If we had used a textbook we would not have been acquainted with the general facts and principles of physics at *first hand*. At best we would have had to take the author's statement of them, and he may have been wrong, as we found when we made the experiment about the weight necessary to break a given substance. Our author said the breaking weight

varied inversely as the area of cross section, and we found by experiment that it varied directly. If we had made no experiment we would never perhaps have known he was wrong. We certainly did learn in our laboratory work how difficult it is for scientists to reach conclusions. There is so much room for error that I scarcely see how they ever reach any definite conclusions. If I learned nothing else, I learned not to be too positive that any conclusion we draw from a statement of facts or from observation is absolutely accurate. I don't think a textbook would ever have shown me this. Often I have crammed the words of a textbook without knowing the meaning of them or getting a single clear idea from them. I could not altogether get rid of the thought that I would have to pass on the required amount of work or take it over again; but in spite of this the experiments were interesting. I think textbook work would have been very uninteresting and hard to understand without actually seeing what took place. Many of the phenomena, especially in electricity, I had never seen, and I don't think a textbook would ever have given me a clear conception of them. I am afraid if we had used a textbook my interest would have been in passing."

EVA BEACH.

"I once took a textbook course in physical geography, and one may not credit this, but not until I began this course in physics did I ever once think of applying the knowledge of geography which I got four years ago to the world about me. Things which the textbook had cited did not attract my attention. I have enjoyed my course in physics a great deal and, as I told my mother Christmas, I think it has tended to make me look at things in a matter-of-fact way more than any other study I have ever had."

BESSIE ROGERS.

"In this work we found out things for ourselves and hence we were impressed with them more than we could have been by simply taking some one's sayings for the truth. In class we all studied the facts together and had things explained which we did not understand. (Many times we had the principal points emphasized and knew which ones to put most stress upon; also points we never would have seen ourselves.) I think this would be an ideal method, if we had time after going over experiments in class, to study the text and thus fix it on our minds. This experimental work is done in the study of botany and zoölogy to some extent, but we use the text to recite from. I have been greatly interested in my work—in finding out things I never knew before. It made me feel better every time I found out some fact experimentally that was hard to understand before seeing it myself. It was much more interesting to learn things experimentally and find out whether the author is correct in all he says than just to take everything for granted. You do not dread to go to such a class room as you do to many other lessons."

EDITH WILLIS.

"There are many things stated in the textbook that I never would have believed unless I had seen them. I might have said that the book said so, and maybe I should have thought so in an abstract way, but they would never have had the same meaning to me. Physics, as a whole, would have been unreal to me. I know this, for when I studied it once before all that I knew was that in a far-off region there was, for instance, such a thing as a lever. I did not know that nearly every kind of machine used *was one,* and that I saw one almost everywhere I looked. As to distinction between fact and theory, I thought everything that I read was fact. My interest might have been, at the first, due only to the fact that I had to do the work, but I am sure that I have never left the room feeling that I had not learned something. I have always enjoyed the work because I was always finding out something new. The course was far more interesting when we had experimental work than when we had the textbook work in the last part of the book. I was then usually glad when the period ended. But I do say that I have enjoyed physics more than any other subject in the junior work."

MAGGIE MCFADDEN.

"One can always realize or take in anything more vividly and lastingly if seen with the eyes or got with some of the senses. An experimental course gives independence to the student and freedom from the servile following and swallowing of the textbook statements. In this way scientific facts and principles become familiar realities to the student—his acquaintance is first hand. The scientific method of investigation is followed in the experimental course and the student gets to know and like it. She gets the habit of sharp distinction between fact and theory inculcated by the handling and investigating of the concrete objects, and can discriminate between actual knowledge gained through the senses and theoretic knowledge arrived at by reasoning and implication. This method enables her to draw and evaluate any kind of scientific conclusions by her practice in deriving, testing and investigating. In general, this course prevents the learning by heart and learning mechanically so prevalent in textbook work and gives life and interest to science. When I began physics my interest was purely to get through, but in working I grew so interested that I would forget about marks, though marks are still of the highest importance in my mind. While studying or working in physics I did not think of passing, but was interested in the subject. There is no comparison between textbook and experimental work; hitherto all sciences have been distasteful to me and caused much memorizing and little understanding and philosophizing, and to my surprise I find that I am sorry to stop physics and that I have learned and can apply some scientific facts to things about me—something before unheard of in me."

SARAH E. REYNOLDS.

THE PROBLEM OF TEACHING DYNAMICS IN THE HIGH SCHOOL.

BY F. D. BARBER,
Illinois State Normal University, Normal, Ill.

No one who has attempted to teach dynamics to high school students will deny that it is exceedingly difficult to lead such students to definite and accurate conceptions of mass, force, velocity, momentum and kinetic energy and their interdependencies. Nor is this to be wondered at. These conceptions are fundamental to nearly all study of physics and, therefore, logically should be treated at the very beginning of the subject, and furthermore they are intrinsically difficult conceptions to master.

The history of dynamics in the sixteenth and seventeenth centuries is a tale of the struggles of Galileo, Descartes, Huygens, Leibnitz and Newton with these same conceptions. Probably only one of these men, Newton, possessed what would pass today in a high school recitation room for a clear, concise conception of the difference between mass and weight. For half a century the Cartesians and the followers of Leibnitz wrangled over the question as to whether the conception known to us as momentum or the other known to us as kinetic energy was the true conception of the efficacy of a moving body. Until very recent times the distinction between force and energy found even in textbooks and works of reference has been confused and misleading. In the case of dynamics, at least, the hard knots in the development of the science have remained the hard knots in the teaching of the science.

The difficulties of teaching this subject are greatly increased by the fact that it is practically impossible even to illustrate in the high school lecture room the real relation existing between force, mass, and acceleration owing to the interference of friction. Again we recall that it was only when Newton turned his attention to celestial bodies unaffected by friction that even his genius could find a verification of the laws in which he had the greatest of faith. Still with all these difficulties confronting us, I do not believe that dynamics should be dropped, or even lightly skipped over in our high schools.

To me experiments performed by the student are most generally serviceable, not so much because they teach new facts, nor, perhaps, because they train the student in what we choose to call scientific thinking, *per se*, but more largely because they afford me the best opportunity to make certain that the student is really thinking over again and again as they appear in new settings and new surroundings, in new garbs and new attires, the few really great, fundamental truths of the physical world. Could we but surmount the obstacle, friction, and devise a set of experiments showing clearly the fundamental relations of force, masses and resulting acceleration, our problem would largely be solved. Since this is impossible, we should, I believe, resort to other means, whenever possible, to lead the student to think over again and again these relations till they became a part of his real knowledge of the world about him even though his observations always show him these relations distorted by friction.

I open a modern and, in the main, very practical high school text to the subject of mechanics. On the first two pages devoted to this topic I see defined: Mechanics, statics, dynamics, kinematics, motion, velocity, and acceleration, together with a brief discussion of the measurement of velocity with the formula: $s = vt$ (Eq. 1), and its modified forms. Then follows on the third page an algebraic development of uniform accelerated motion with a culmination every two lines in the form of an algebraic equation: $v = at$, (Eq. 2); from this $a = v/t$, and $t = v/a$; $s = at/2 \times t = \frac{1}{2} at^2$ (Eq. 3), from which can be derived $a = 2s/t^2$, and $t = \sqrt{2s/a}$. Combining (2) and (3); $s = v^2/2a$ (Eq. 4), from which $v = \sqrt{2as}$, (Eq. 5). The space passed over in t seconds being $s = \frac{1}{2}at^2$, the space passed over in $t-1$ seconds will be $s' = \frac{1}{2}a\,(t-1)^2$; hence, the space passed over in any given second will be $s'' = s - s' = \frac{1}{2}\,at^2 - \frac{1}{2}a\,(t-1)^2 = \frac{1}{2}a\,(2t-1)$ (Eq. 6), all of which is undoubtedly true, but nevertheless I ask: Is this the royal road along which we are to lead our boys and girls into the field of dynamics? Is this the best introduction we can give the average boy or girl to these fundamental truths of physics? I do not think so.

I may be mistaken. This may be very interesting reading and

its mastery a very easy task for the average high school student. But, granting all this, does not Dr. Hall state facts when he says: "The formulas, at least for cases of uniform accelerations, are very simple, but the primary conceptions underlying these formulas, the definite notions of force, momentum and kinetic energy, the ordinary student rarely masters and retains"? If this statement be true then in the light of modern scientific method such students have little business handling these formulas as an introduction to the study of dynamics. For the most part work with these formulas, *i. e.,* handling them as an algebraic expression of facts, must, at this time, be nearly or quite empty of educational value as science. Frequent exercise in solving problems by the use of these formulas are all too often a sham, a pretense at having acquired something worth knowing, whereas, in fact, temporary memorizing has alone prevailed. All too often we might safely apply to such exercises the definition which the boy is said to have given for a lie: "An abomination before the Lord, but an ever present help in times of trouble." The teacher is too often convinced, I imagine, that the abomination must be endured, that there is no help for it. Dynamics must be taught; solving problems seems to fix the formulas in the minds of the students; numerous laboratory problems to clarify the subject are out of the question; *ergo,* we will memorize the formulas and solve problems. I do not believe that the case is so hopeless.

To illustrate what I have in mind as a substitute for laboratory exercises in dynamics, I shall state briefly my plan of presenting the subject in its earlier stages.

Following a statement of the definitions of mass, weight, force, velocity and acceleration I usually suspend two iron balls from the ceiling of the lecture room. The balls weigh six pounds each and are suspended about six or eight inches apart. A light flexible cord is passed from one of the balls through a pulley and back to the other ball. A rather sharp, quick pull in a horizontal direction gives to each ball a considerable velocity. The acceleration given the two balls is evidently approximately equal. It is necessary at this time to make sure that the student sees that the function of the pulley is simply to divide the entire force of

the pull equally between the two balls. I then substitute a twelve pound ball for one of the six pound balls. A similar sharp pull now produces unequal acceleration in the two balls, the lesser

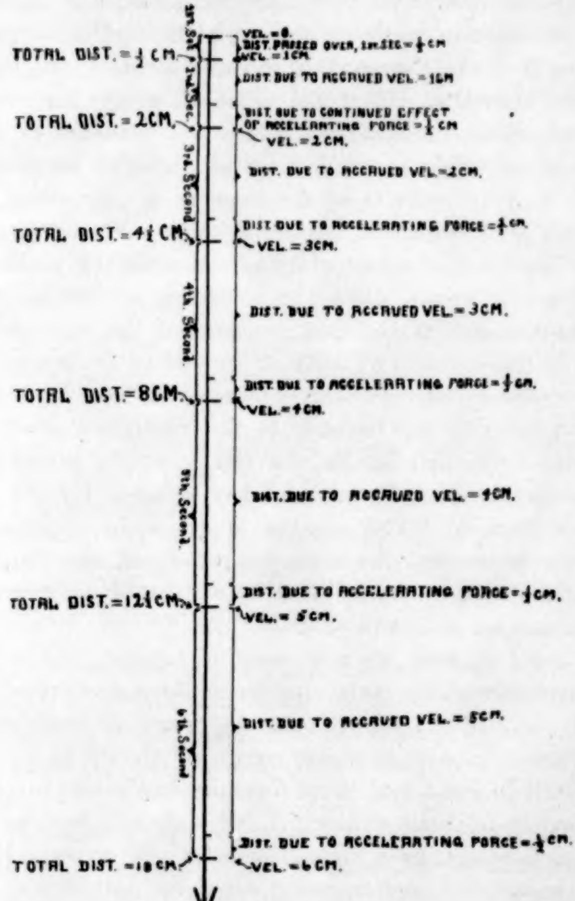

FIG. I.—Analysis of motion produced by one dyne of force acting upon one gram of mass for six seconds.

mass receiving the greater acceleration. This qualitative experiment easily teaches that equal forces acting for equal periods of time upon equal masses produce in them equal acceleration, and

acting upon unequal masses produce unequal acceleration, the lesser mass receiving the greater acceleration.

As soon as the units of force, the dyne and the poundal, are defined the student is required to picture graphically, as well as mentally, the motion resulting from the effect of a force of one dyne acting for, say five seconds, upon a mass of one gram in a horizontal direction. That the effect of weight may be more easily dismissed by the student, he may well be asked to conceive of the mass as being suspended by means of a cord of great length, or he may conceive of the mass as sliding along a horizontal track with which it has no friction. The student must construct his graphic representation to a scale (Fig. I) and it must tell all he knows about the movement of the body, *e. g.*, velocity at the end of the first second and the distance passed over during that second; velocity at the end of the second second and the distance passed over during that second, due, first, to accrued velocity, and second, to the continued effect of the accelerating force, and finally, the total distance passed over in the two seconds. Such an analysis may be made for any number of seconds required. The exercise is varied by requiring such an analysis when any given number of dynes are acting upon one gram of mass, or again when one dyne of force acts upon any given number of grams of mass.

For the first time we now examine together and as a class the numerous formulas pertaining to uniform accelerated motion previously quoted. If the student has done his work well and independently, he now has most or all of the fundamental conceptions well in hand and these formulas can easily be shown to express merely relations with which he is already familiar.

We next study, as a class demonstration, an actual case of uniform accelerated motion using Galileo's device, the inclined plane decomposing the acceleration of gravity. The student is required to lay off a representation of the plane, always drawing to a scale, and then trace the body down the plane, indicating its position at the end of each second. (See line 1, Fig. II.)*

From the data of the first second the student is led to reason

*These data are from actual experiments and, of course, are not theoretically accurate.

about as follows: Since the body was observed to pass down the plane 16 cm. during the first second, its *average* velocity for that second was 16 cm. per second. But since this is a case of uniform acceleration, *i. e.,* uniform gain in velocity, it must have had its average velocity at the middle point of time or at the end of half a second, and its *final* velocity must be 2 × 16 cm., or 32 cm. per second. Further, since the initial velocity was zero and the final velocity for the second was 32 cm., it follows that the acceleration of this body down the plane, judging from this first second, is 32 cm., per second.

In a second plane parallel to the first the student now traces the ball down the plane, using the same scale as before, and sup-

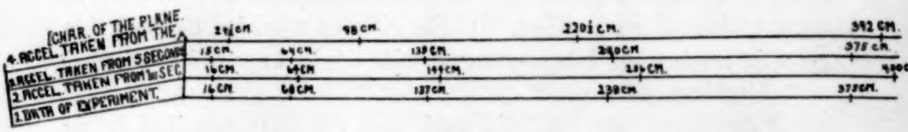

FIG. II.—Analysis of the motion of a ball passing down an inclined plane.

Four cases:

1. Data of the experiment.
2. Acceleration taken from the first second.
3. Acceleration taken from the distance passed over in five seconds.
4. Acceleration taken from the character of the plane; height of plane one foot, length of plane thirty feet.

posing that the observations of the first second were without error. (Line 2, Fig. II.) In a third plane (Line 3, Fig. II) the path is laid off according to the acceleration as obtained by supposing that the observation of the distance passed over in all five seconds was correct.

The character of the plane used, *i. e.,* the length and height of the plane, is recorded at the time of the experiment. After the law of the inclined plane has been studied the student is required to return to this exercise and trace the motion of the ball down the plane, taking the acceleration this time from the character of the plane. A brass sphere one and one-half inches in diameter running on a smooth, grooved, hardwood track which rises about one foot in eighteen or twenty feet will have its theo-

retical acceleration cut down by friction about one-third, thus adding a new fact which the student must explain.

When a student who has done this work passes to the study of freely falling bodies he finds little that is new. It is seen to be simply a case of the ball passing down an inclined plane inclined ninety degrees or vertical. The motion of the body is completely analyzed in the same way that the motion of a gram of mass impelled horizontally by a dyne of force was analyzed. The relation between a dyne of force and a gram of force should now be clearly understood, and the foundation laid for an understanding of all the units, absolute and gravity, of force and work.

I have no thought of presenting a complete outline for the study of dynamics, but merely to present a method of procedure in the teaching of that subject. If the Atwood machine be used this graphic method of interpreting results could be readily adapted and, I believe, with profit.

"But," you ask, "is this work and the time required to do it worth the while?" I reply: In my judgment, I find it so in practice. I believe that the average normal school student, and the same is true of the average high school student, does not easily and will not readily assimilate a purely mathematical development of the laws of dynamics. If you can lead him or her actually to live with the moving body till its characteristic motion becomes a fact of personal experience, there will be little need of requiring a memorizing of those formulas, those will-o'-the-wisps, which ever delude the student at the critical moment.

A prominent and successful high school teacher recently told me that he had practically given up teaching falling bodies to his high school students because they did not receive sufficient benefit to pay for the time and energy spent upon the subject. Such important and common phenomena should not be left without explanation. It seems probable that some mode of presentation can be adopted which will make the subject comprehensible to high school students.

In conclusion I do not wish to be understood as discountenancing all solving of problems as a means of clarifying and fixing general principles. Such exercises are invaluable if rightly con-

ducted. But too often the problems found in texts are foreign to the student's life and are therefore thought to be "catchy," whereas they are senseless. There can be no question but that problems which can be taken from the student's experiences, and especially in the early part of the work those which can be solved graphically, should be given freely. At no time in the teaching of dynamics should an exercise be accepted as having educational value which consists in the student's selecting the proper formula, substituting the values named in the problem, and "solving," as he says. To know the principles of dynamics is simply to be able clearly to picture the motion of a given mass when acted upon for a given time by a given force.

PLANTS AS PETS.

BY EDWARD F. BIGELOW,
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In many schools space and earth are not always available for growing plants. But, fortunately for the purposes of study, observation and caring for the plants as pets, earth is not needed and the space required by artificially fed plants is very small.

Plants naturally grown in soil, even in the richest, require large root surface to explore every tiny "nook and cranny" of the underground part of the home of the plant. Not a particle of food within the area must be missed. But it is the food percolating through the soil that the plant requires. Plants may be fed with the required chemicals, and not greatly inconvenienced by the lack of soil.

One of the best of artificial foods is that known as the Sachs nutrient solution, commonly used for experimental purposes in every botanical laboratory.

The writer has extensively supplied this food in tablets convenient for use in any school room as follows:

		Metric weight [nearly]
Common table salt (sodium chloride, $NaCl$)	2½ grains.	.162 grams.
Plaster of Paris—Gypsum (calcium sulphate, $CaSO_4$)	2½ grains.	.162 grams.

Epsom salts (Magnesium sulphate, $MgSO_4$)
2½ grains. .162 grams.
Phosphate of lime, nearly the same as burned bones.
(Calcium phosphate, $Ca_3 (PO_4)_2$
2½ grains. .162 grams.
East India salpetre—Nitre (potassium nitrate, KNO_3)
5 grains. .325 grams.
Compound of iron and chlorine (ferric chloride, $FeCl_3$)
nearly 1-10 grain.

DIRECTIONS—To make the food solution, two of these tablets are required for each pint (500 ccm. nearly) of water. Crush the tablets to be used and put the powder in the water. Shake or stir thoroughly before using. Keep the plants thoroughly moistened with this solution, which is both drink and food for them.

By using a nutrient solution made from these tablets all that is needed is some material, such as sawdust, pebbles, shot, beads,

WHITE LUPINES, MILLET, OATS AND VETCH IN SAWDUST IN EGGSHELLS.
The plants may thus be grown at least two feet tall. In a similar manner a garden may be grown in clam shells, small tin cups, etc. The roots of artificially fed plants require but little room.

broken bits of brick—anything in pieces that will not decay—through which the roots may pass to seek the food applied to the artificial soil.

These chemicals can be obtained in bulk from almost any chemist or at most drug stores, or a box containing thirty compressed tablets will be supplied by the writer, with full directions, upon receipt of ten cents. (Two cents of this is for postage.)

A solution made from these tablets is the food required by most plants. This solution does not germinate the seeds, it feeds the plant from the first appearance of the tiny roots.

Let the seeds germinate in moist warm air supplied in any manner, perhaps the most convenient material is cotton batting. Then the plant may be placed on mosquito netting stretched across the top of a tumbler or other receptacle, full of the solution or in sawdust, pebbles or in almost any material kept wet with the

A "HILL" OF BEANS GROWING IN SAWDUST IN AN OLD DRIPPING PAN.

solution. A fine crop may be grown in brick dust or pieces of brick in an old tomato can or in a bowl filled with sand or with pulverized stone from a macadamized road. All that is needed is a receptacle through which the roots may penetrate in darkness. You supply the food and nature does the rest. If the growth is on a net stretched across a transparent vessel containing only

the liquid with no opaque objects among which the roots may naturally shun the light, heavy paper or black cloth should be wrapped around the glass, the wrapper to be removed whenever it is desired to examine the roots of the plant.

By this process there is no limit to the novelty of methods, and novelty always pleases and attracts children. There is also the added advantage in bringing the plants under close observation—as pets, the children call them. A plant grown on a tumbler in a desk by the child is more apt to become an object of real love than the plant down in the garden. The progress of the plant is eagerly watched from day to day. A few new root hairs is an event of great interest.

Plants may be grown on a shelf or from open mouthed bottles hanging on chandeliers or by the window. A large plant may be grown in a small receptacle for plants artificially fed, seem not to require as many roots as when they must search over a great extent of soil for the food. The accompanying illustrations show three methods of novelty and suggest many others.

DO GRASSHOPPERS DRINK?

BY CHARLES D. SNYDER,

Lowell High School, San Francisco, Cal.

Who has ever seen a grasshopper drink? We are all familiar with "where the bee sucks," and the mosquito, too, but where and when does the grasshopper, the locust, suck? We are familiar enough with the sight of these sphinx-faced creatures eating—eating with a seriousness and solemnity as though all heaven and earth depended upon the operation. Vegetarians that they are, seeking out the tenderest dew-ladened morsels the fields afford, they certainly have very little occasion actually to leave off eating and go to drinking. And when this does happen it is most probable that few people indeed observe the process.

It was the good fortune of the writer during the past fall to see several specimens of *Melanoplus* drink great draughts of water. He had never before seen any kind of a grasshopper

drink; he had never heard or read of them drinking; so he watched them with a great deal of interest. After describing the incident to others it seemed worth while to write out the following account of what was observed:

A number of Rocky Mountain locusts, obtained from the San Joaquin Valley, were kept alive in a big glass aquarium jar, covered over with a piece of cheesecloth. The animals were supplied daily with fresh bits of green plants, bluegrass, alfalfa, clover, mallow, dandelion or filiree. They ate heartily of this food and seemed perfectly contented. But during a vacation period they were somewhat neglected, and one morning a few were found dead. Their bodies seemed to be exceedingly dry.

From this time on they were fed regularly again with fresh green plants, but nevertheless deaths continued to occur. The tissues of the bodies of all the dead ones were in the same desiscated condition. It was concluded that their food did not supply the insects with enough water.

A dish of water had been kept in the cage from the first. This was done out of mechanical habit rather than from any real expectation that the animals would actually drink from the dish. For who ever saw such creatures drink? And how could they, with their stiff mailed necks and their hard, ill-made lips?

But the animals were dying and something had to be done. It was decided to thoroughly wet down the sand that covered the bottom of the jar. It was thought that this would at least increase the humidity of the air surrounding the insects and thus decrease the evaporation from their bodies until a better method of supplying them with water could be found.

Accordingly water was sprayed through a sprinkling can into the aquarium jar. The sides as well as the dry sand on the bottom were given a generous wetting. The water soaked into the sand at once, but gathered on the sides of the jar in drops.

The insects were busy feeding on some slender stems, but as soon as they had been treated with this shower-bath they left the plants and moved restlessly over the floor. Finally one touched against the side. She quickly swept her antennæ over its surface, A large drop of water was soon touched, and with a precision and

deftness that could only be the result of previous experience she at once had her lips and mandibles surrounding the globule of water. The globule disappeared. A number of such drops were then taken up in a similar manner. Within a few minutes all the other grasshoppers had found drops of water on the sides of the jar, and, standing on their hind legs, were straining in every direction to suck up the thirst-quenching liquid.

At no time during their captivity were these animals seen to sip water from the dish that was placed in their cage. It would, however, have been possible for them to have dipped their mouths into the water with safety and convenience had they tried to do so. Their thirsting condition was evidence that they had not tried. Their restlessness and immediate search for water droplets after the shower is evidence that they probably can "scent" water, especially when it is in the form of raindrops, or, better, when it has passed through the air in a finely divided condition. The food given the animals was rarely drenched with dew. The insects did not know that water was present in the dish all the time they were thirsting. They could not drink from a dish because they never had done so. Animals do not carry around with them useless knowledge.

In a state of nature *Orthoptera* generally can keep their bodies supplied with what water they need by sucking up drops of dew which, during the early hours of the day, are plentiful enough on the surfaces of natural objects.

The lips, maxillæ and mandibles of these animals are built specially for biting purposes, but are so arranged with reference to one another, to the tongue and the walls of the mouth cavity, that they may also be used when needed as suctional organs.

A SIMPLE DEVICE WITH CHEMICAL EQUATIONS.

BY ELDRED E. JUNGERICH,
Midvale Steel Company, Philadelphia.

The coefficients of the components of the most complicated chemical equations may be found in a simple way as soon as the character and number of substances on each side of the sign of equality are correctly stated. Yet neither in the elementary or advanced courses of descriptive chemistry I have attended, or in articles I have read, have I seen this fact made clear. The student is, of course, told that it is important to know the reagents and products of the given reaction as well as the valencies of its radicals, before attempting to write down the coefficients. But beyond this point he is shown no better way of obtaining these coefficients than a loose fashion of hit and miss guessing that requires an elaborate verification for each guess made. The simple device I herewith submit I have used advantageously for five years. As will quickly be seen it makes the solution of the equation dependent upon a simple algebraic equation of the first degree, the few instances where it does not reduce it to a matter of mere inspection.

In the following graphical statements, the unknown symbol without subscript is the coefficient of the component taken as a starting point. The same symbol with the subscript (1) is attached to all components immediately derivable from this primary component. The symbol with the subscript (2) will be attached to a component derivable from one having subscript (1), and so on.

To illustrate the convenience of the device it will be enough to consider the determination of the three following equations:

First.—The preparation of nitric oxide from copper and nitric acid.

$$Cu+HNO_3=Cu(NO_3)_2+NO+H_2O.$$

Write x as the coefficient of Cu and y as that of HNO_3, and the entire equation is at once seen to be the following:

$$xCu+yHNO_3=x_1Cu(NO_3)_2+(y_1-2x_2)NO+y_1H_2O.$$

The algebraic coefficient of the nitric oxide is easily seen to

satisfy the condition that the nitrogen in it must be the excess nitrogen of the nitric acid over that in the copper nitrate.

The relation of x to y is found by equating the atoms of oxygen, there being the same number on each side of the equation.

$$3y=6x+y-2x+\frac{y}{2}$$

or

$$y=8/3x.$$

Substituting the value of y, clearing fractions and dividing out x common to all the terms, we get finally:

$$3Cu+8HNO_3=3Cu(NO_3)_2+2NO+4H_2O.$$

Second.—The preparation of carbon monoxide from potassium ferrocyanide.

$$xK_4Fe(CN)_6+6x_2H_2SO_4+6x_{2a}H_2O=3x_1(NH_4)_2SO_4+6x_{1a}CO$$
$$+x_1FeSO_4+2x_1K_2SO_4$$

Cancelling x, we get the usual form:

$$K_4Fe(CN_6+6H_2SO_4+6H_2O=3(NH_4)_2SO_4+6CO+FeSO_4+$$
$$2K_2SO_4.$$

The coefficients of $(NH_4)_2$ SO_4, CO, $FeSO_4$, K_2SO_4 were all obtained directly from the coefficient of $K_4Fe(CN)_6$. The coefficient of H_2O was obtained from that of CO; and that of H_2SO_4 from summation of coefficients of the sulphates. The device in obtaining this equation amounts therefore to mere inspection.

Third.—The oxidization by permanganate of ferrous to ferric sulphate.

$$xKMnO_4+yFeSO_4+4x_2\ H_2SO_4=x_1MnSO_4+x_{\frac{1}{2}}K_2SO_4+y_{\frac{1}{2}}$$
$$Fe_2(SO_4)_3+4x_{1a}H_2O.$$

The coefficient of H_2SO_4 is obtained from that of H_2O.

To find the relation of x to y, we equate the molecules of SO_4 on each side of the equation.

$$y+4x=x+\frac{x}{2}+3\frac{y}{2}$$

or

$$y=5x.$$

Substituting, clearing fractions and dividing x common to all terms, we get

$$2KMnO_4+10FeSO_4+8H_2SO_4=2MnSO_4+K_2SO_4+$$
$$5Fe_2(SO_4)_3+8H_2O.$$

I have made use of this device to obtain equations which have coefficients as high as 34 or 45 (these are met with in reactions with molybdesnum, vanadium, etc.), and in none of the cases considered did I encounter greater difficulty than in the specimen equations given in this paper. The device is therefore one of great convenience. It will save the chemist the labor of burdening his memory with a mass of formulas or the trouble of searching for them in some standard work. A very little practice with it will soon make it an implement of great value.

A NEW LECTURE-TABLE EXPERIMENT WITH PHOSPHORUS.

EDWARD H. KRAUS, PH. D.,

Syracuse, (N. Y.), High School.

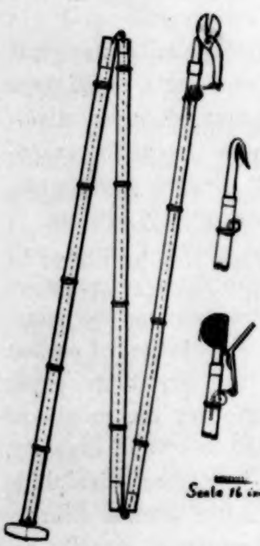
The activity of phosphorus, and more especially its great affinity for oxygen, is usually illustrated by dissolving a small piece of yellow phosphorous in a few cubic centimeters of carbon disulphide and pouring this solution on filter paper. Upon the evaporation of the carbon disulphide, the finely divided phosphorus, which is now evenly distributed over the paper, quickly ignites.

The following simple modification of the above, I think, will commend itself as well adapted for a lecture table or so-called "teachers'" experiment. Instead of hanging or waving the moistened paper in the air in order to hasten the evaporation of carbon disulphide, as Remsen recommends, place the dry filter paper (paper 11 cm. in diameter gives the results) over the mouth of a strong, empty, salt-mouth bottle of about 350 to 400 cc. capacity. Pour enough of a solution of phosphorus in carbon disulphide upon the filter so as to wet it thoroughly. After several minutes the phosphorus will ignite and the burning paper, usually accompanied by a loud report, is hurled several feet into the air. During the evaporation of the carbon disulphide, a considerable amount of its vapor settles into the bottle. The mixture of the carbon disulphide vapor and air in the bottle explodes when the phosphorous takes fire.

A FOLDING COLLECTION POLE.

BY LOUIS MURBACH.

In larger cities where the science teacher has to go great distances on cars to reach favorable collecting grounds, it is desirable to have all collecting paraphernalia in as compact form as possible, and the folding feature applied to such an unhandy piece as a tree trimmer, which it is sometimes desirable to take into the field, may interest others. Tree-blossoms are soon picked as far as people can reach or are altogether out of reach. Desirable insects may alight on shrub or tree just a little above your arm's length, or it is desired to draw in some object from the bank of a stream. A tree pruner could be made to serve these purposes and if it were jointed it could be conveniently carried in transit.



Scale 16 inches.

All the material necessary, a large bamboo pole, a pair of pruning shears (Cronk), a piece of No. 10 wire ($\frac{3}{32}$ inch) as long as the pole, double brass ferrules for the joints of the pole, a piece of $\frac{1}{8}$-inch steel chain seven inches long, a half-inch brass pulley, may be obtained at a hardware store. The insect net and a hook can be provided in a similar way.

Cut the pole into suitable lengths to carry folded, say three to four feet. Fit the cut ends into the ferrules by means of a coarse file. Cut a piece of wire about half a foot longer than a section of your pole, and sharpen one end in drill or bit shape. Use this to bore holes through the partitions at the joints of the pole.

Fasten some sort of stout handle (mine is a gimlet handle) to the end of the first section of wire and pass the wire through the lowest section of the pole. Draw the handle against the lower end of the pole and bend an eye in the opposite end of the wire, cutting off the wire at the level of the brass ferrule. Join the next section of wire to this one by

an eye and pass through the next section of the pole the same as the first, so that the wire joint will come at the end of the ferrule when the pole is folded.

The top section of the pole is to be cut so that the hole in the end of the pole will snugly fit one handle of the pruning shears. A ferrule or wire will keep the end of the pole from splitting. Set the pulley into the upper section of the pole just under the end of the pruning shears when in place. The eye in the last wire section comes just under the pulley, and to it should now be attached the piece of chain so that it will easily work over the pulley. If you can not drill a hole in one arm of the pruning shears for fastening the chain, then file a groove around the end of the handle and bend a steel wire—a nail will do—into the groove, with an eye for holding the chain. The chain, of course, must be long enough to allow the pruning shears to stand fully open. When the pole is set up the shears are operated by pulling the handle at the lower end.

For collecting insects on trees it is simply necessary to substitute a net whose handle will fit in place of the pruning shears and provided with a lid that is held shut by a soft spring and opened by a pull at the bottom of the wire in the pole. With a cutting hook in place of the pruning shears, water-weeds or sticks can be cut off and pulled in from the bank of a stream. No doubt other uses might be suggested.

TWO NEW QUANTITATIVE EXPERIMENTS.

BY RUFUS P. WILLIAMS.

Two experiments I have never seen described are given below. Both were devised and made this year in our laboratory, the second one having been originated and worked out by one of my first year students, H. L. Lurie. Both can easily be done by a class.

Experiment 1.—*Volumetric Composition of Nitrogen Peroxid.* —A 50 cm.^{3} graduate is filled with water, inverted over a trough and clamped in position so as to have 40 cm.^{3} above the water

in the trough. With a nitrogen dioxid generator (Cu & HNO_3) collect 40 cm.^{3} of NO in the graduate, being sure it is not contaminated with air.

In another graduate similarly arranged collect 20 cm.^{3} of pure oxygen ($KClO_3$ and MnO_2 heated). Keeping the mouths of both graduates under water pour the oxygen not too fast up into the dioxid. The latter is very rapidly changed to the higher oxid and as quickly absorbed by the water, which almost or quite completely fills the graduate if the experiment is carefully made, thus showing that 20 cm.^{3} of oxygen unite with 40 cm.^{3} of the dioxid; or $O_2 + 2NO = 2NO_2$. On experimenting with larger volumes of oxygen, *e. g.*, equal volumes of each gas, the excess of oxygen will be found to displace the proportionate amount of water.

By taking variable quantities of the two gases the *law of definite volume* can be illustrated while the experiment, as above made, illustrates the *law of multiple volume,* assuming, of course, that the dioxid contains one volume of oxygen.

Experiment 2.—*Volumetric Percentage of Oxygen in Air.*—This experiment is similar to the previous except that atmospheric air is substituted for oxygen. The approximate volume of air needed to furnish enough oxygen to combine with the NO may be computed, or the student may work with variable volumes till he gets the right one. A little care is needed in entrapping the desired volume of air, which must be poured upward more slowly than was the oxygen. When carefully done it gives excellent results as regards volumetric percentage, much better than the phosphorus-oxygen experiment.

NOTES ON THE PROGRESS OF CHEMISTRY—II.

BY LYMAN C. NEWELL, PH. D.

The first article in this series was published in Vol. II, No. 4 (October, 1902, page 229).

International Catalogue of Scientific Literature, D—Chemistry (Internat. Cat. Sci. Lit., 2 (1902), pt. 1, pp. 468.) "This catalogue is being prepared by a central bureau in London under the directorship of H. F. Morley and by twenty-nine regional bureaus in different countries. The supreme control of the catalogue is vested in an international convention, to meet in London in 1905, 1910, and every tenth year thereafter. In the interval between successive meetings the administration is vested in an international council consisting of one representative from each regional bureau. The plan adopted provides for author and subject indexes for the different branches of science, which have been arranged in seventeen groups. This volume, for which E. Goulding is referee, is an incomplete index of the literature of chemistry during 1901, the publication of the second part of the volume being promised in a few months."

Platinum. (1) Recent Advances in Our Knowledge of the Metals of Platinum Group, *Amer. Chem. Jour.*, Jan., 1904, page 63. (2) Geological Relations and Distribution of Platinum and Associated Metals, Bulletin 193 (Reprint), U. S. Geol. Survey. The first article is a report by Prof. James Lewis Howe on the contributions to this subject made during 1897-1903. It comprises about twenty pages and is a complete resumé. "Localities and output have undergone comparatively little change," though several regions have been studied, especially the Tulameen district in British Columbia. An account of this last locality forms a large part of the second article. "Platinum in the form of spirrylite ($Pt\,As_2$) seems to be a constant accompaniment of the Sudbury, Ontario, nickel ores, and is concentrated in the matte to the extent of about 50 grams of platinum per ton of nickel." In the Bulletin by Professor Kemp there is a review of all the occurrences of platinum. "He inclines to the opinion that platinum has been deposited from fusion."

"No subject connected with the platinum metals has recently attracted more attention than the work of Bredig and his followers on colloidal platinum as an inorganic ferment. In 1898 an apparent solution was obtained of a dark wine color, which did not clear up in weeks and which was very active in promoting those so-called catalytic actions which have long been known to be brought about by finely divided platinum. It was soon found that this solution, now known as colloidal platinum, possesses many of the properties of an organic ferment, and, like the latter, is so affected by the presence of certain salts and other substances that it is no strained application of the term to speak of its being poisoned."

Professor Kemp's bulletin besides giving many facts about the composition of platinum ores, contains six plates and nine illustrations (two of the plates being colored), and a map of the platinum region of British Columbia. It can be obtained without cost from the Director of the U. S. Geol. Survey, Washington, D. C.

Quartz Apparatus.—In a review of the progress in industrial chemistry Thorp says: "The manufacture of chemical vessels of fused quartz has reached a successful issue in Germany. Dishes and crucibles are now articles of commerce. Owing to the very low coëfficient of expansion of quartz it is little affected by extremes of heat and cold, and its inertness makes it useful for acid vessels, pump valves, etc. It withstands water, acids and neutral salts, but not alkaline liquids and dry oxides at high temperatures. Being transparent to ultra violet rays of the spectrum, fused quartz is suggested for vacuum tubes." Quartz vessels can now be obtained of American dealers. (*Jour. Amer. Chem. Soc.*, Feb., 1904.)

Nickel-Steel.—By Crittenden Marriott. *Sci. Amer.*, July 11, 1903, page 23. Alloys of these metals have been investigated by Charles E. Guillaume, of the International Bureau of Standards.

Regarding the properties of alloys of nickel and steel, a writer in the *Forum* for July-September, 1903, page 60, says: "One of the most remarkable of these is the fact that certain alloys of steel and nickel possess much lower coëfficients of expansion than either of the constituent metals. The alloy which has attracted the greatest attention is the minimum-expansion alloy, containing thirty-six per cent of nickel; this has only one-fourteenth the expansion of platinum for any given increase of temperature, thus being extremely useful for the construction of standards of length, measuring tapes, clock pendulum bars and the like. Thus M. Guillaume states that a unit of the thirty-six per cent alloy, one kilometer long, varies in length less than 0.4 mm. in passing from 0° to 20° C.! A more recent application of this property is found in the possibility of varying the proportions of steel and nickel so as to produce an alloy having the desired coëfficient of expansion. In the construction of incandescent electric lamps and other apparatus requiring metal connections to be fused into glass, it has been found necessary to use platinum wire because that metal expands and contracts almost exactly the same as glass. M. Guillaume has succeeded in making a nickel-steel alloy having precisely the same coëfficient of expansion as that of glass, and wire of this alloy is used to replace platinum in many places in which the fusion in glass is necessary."

Oxygen-Acetylene Blowpipe.—*Forum*, July-September, 1903, page 64. This new apparatus is "practically identical with the oxy-hydrogen blowpipe, with the exception of the substitution of acetylene gas for the hydrogen. The high calorific power of the acetylene renders it possible

to produce in this way temperatures exceeding 4,000° C., while the readiness with which acetylene can be generated from calcium carbide and water obviates the difficulty of procuring hydrogen. The heat produced by the oxygen-acetylene blowpipe is so great that any of the metals used in the arts may be readily fused, while the welding of steel or iron may be effected with ease and certainty."

Atomic Weights.—The table of atomic weights for 1904, prepared by the international committee is the same as that for 1903 with two exceptions, viz.: Cæsium becomes 132.9 and cerium 140.25 (O=16). (*Jour. Amer. Chem. Soc.*, Jan., 1904, page 1.)

Diamonds.—Artificial diamonds have recently been made by an interesting process. "By using a modification of the Goldschmidt process, the magnesium, aluminum and oxides being taken in such proportion as to form the natural matrix of the diamond, von Hasslinger has succeeded in converting finely divided graphite into clear, octahedral diamonds 0.5 mm. in diameter. The diamonds are formed by slow cooling in absence of any considerable pressure." (*Journal American Chemical Society*, December, 1903, page 1284.)

Apropos of the above we should note the following item, which appeared in *Science* for February 12, 1904:

"It has been very generally accepted that Moissan prepared diamonds synthetically by chilling an iron rich in carbon, the supposition being that in the interior of the mass of iron, solidified on the exterior, the pressure on solidification must be intense, and that under these conditions the carbon crystallized in the form of diamond. This position is very strongly attacked by C. Combes in the *Moniteur Scientifique.* In this paper he argues that Goepert and Friedel have found plant remains in diamonds, showing that the crystals must have been formed at a temperature below at least 772°. At the temperature of fused cast iron the diamond is converted into graphite. The diamonds supposed to have been formed by Moissan were doubly refracting and were not diamonds. Moissan's analyses of his crystals were unsatisfactory for diamonds. Finally Friedel has proved that such a mass of iron as was used by Moissan really contracts on cooling instead of expanding and hence the supposed pressure was not present. Thus it appears to Combes impossible that Moissan has prepared diamonds."

Bacteria and the Nitrogen Problem.—By George T. Moore. Yearbook U. S. Dept. Agr., 1902, page 333. *Nitrogen-fixing Bacteria.* By J. S. Lipman. *Pop. Sci. Mo.*, December, 1902, page 137. These articles confirm previous views regarding the fixation of atmospheric nitrogen by bacteria, though both note the fact that nitragin—the artificial culture of the bacteria used to inoculate the soil—is no longer an article of commerce, its use not having met the expectation of the projectors.

The first article can be obtained, as a reprint, from the Secretary of Agriculture, Washington, D. C.

Since the above articles were published, the matter has taken an expected and propitious turn. We quote from President Remsen's address on Scientific Investigation and Progress (*Pop. Sci. Mo.,* February, 1904, page 291): "According to the most reliable estimates the saltpeter beds will be exhausted in thirty or forty years. Is there a way out? Dr. Frank (and others) show that there is. In the air there is nitrogen enough for all. The plants can only make a limited use of this directly. For the most part it must be in some form of chemical combination as, for example, a nitrate of ammonia. The conversion of atmospheric nitrogen into nitric acid would solve the problem, and this is now carried out. But Dr. Frank shows that there is another way of geting the nitrogen into a form suitable for plant food. Calcium carbide can now be made without difficulty and is made in enormous quantities by the action of a powerful electric current upon a mixture of coal and lime. This substance has the power of absorbing nitrogen from the air, and the product (calcium cyanamide) thus formed appears to be capable of giving up its nitrogen to plants, or, in other words, to be a good fertilizer. It is true that the subject requires further investigation, but the results thus far obtained are full of promise."

The technical account of this new process is in the Experiment Station Record (U. S. Dept. Agr.), Jan., 1904, page 424, and the *Jour. Amer. Chem. Soc.,* Feb., 1904, page 214); a brief account is published in *Science,* Jan. 29, 1904, page 197.

Brief Bibliography of Radium (popular articles).

(a) Radio-Activity, *Harpers,* August, 1902, page 357.

(b) Radium and Its Recent Development, *Scientific American Supplement,* July 25, 1903, page 203,042.

(c) Wonders of Radium, *McClures,* November, 1903, page 3.

(d) Spinthariscope, *American Journal of Science,* July, 1903, page 99.

(e) Home-Made Spinthariscope, *Scientific American,* January 2, 1904, page 8.

(f) Disintegration of the Radioactive Elements, *Harpers,* January, 1904, page 297. (This is by Ernest Rutherford, and is one of the most accurate articles.)

(g) Radium and Its Mysteries, *Scientific American,* January 2, 1904, page 9.

(h) Radium and Its Wonders, *Review of Reviews,* November, 1903, page 585. (Very complete.)

(i) The New Element, Radium, *Century,* January, 1904, page 451.

(j) Radium and Radioactivity, by Mme. Curie, *Century,* January, 1903, page 461.

(k) The Action of Radium, Röntgen Rays and Ultra Violet Light on Minerals and Gems, *Science,* December 18, 1903, page 769.

Metrology.*

THE METRIC SYSTEM PSYCHOLOGICALLY CONSIDERED.

BY WILLIAM F. WHITE.

(*Continued from page 45*)

The large number of men who are mentally alert might justify the prediction of Lord Kelvin before the English committee: "I believe that the difficulty of making the change has been enormously exaggerated. I believe that in a fortnight people would become so accustomed to the perfect simplicity and easy working under the metrical system that they will feel that instead of its being a labor to pass from one system to the other, it will be less than no labor—that is to say, it would be a very great saving of labor after the first day or two of beginning to use the metrical system."[11]

But we are not left to the opinion of even the most eminent of scientists: we have the experience of Germany and Norway and Sweden and other countries. For official testimony concerning the ease with which the metric system was introduced in the countries named, see the reports made by the committee on coinage, weights, and measures to the United States house of representatives in 1896 and 1897.

We not only have the experience of most other nations on this point, but any interested individual can satisfy himself from his own experience. The "hardship" of learning to think in terms of a new system of weights and measures is amusing to anyone who has become acquainted with the metric system by a little use of it.

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[11]Report from the committee on coinage, weights, & measures, on H. R. 2758. Report no. 795, 54th cong. 1st ses. p. 18.

The difficulties in the way, both physical and mental, are so often overstated that it is of importance to keep in mind that the metric system has been introduced by many other nations and without the predicted trouble, that the forebodings of inconvenience in making the change might have some weight if the thing had not previously been done by anybody, but that to all the theorizing there has been applied the check of actual experience. "The difficulties may be likened to those which made it clear to thoughtful minds sixty years ago that no steamship could ever cross the ocean because it could not carry coal enough to make so long a voyage."[12]

The foregoing presentation, though brief and incomplete, may serve as a basis for the following contention for compulsory legislation and for adequate teaching of the metric system.

COMPULSORY ADOPTION OF METRIC SYSTEM IN UNITED STATES.

Should there be compulsive legislation? This is an inquiry in the field of political science—a question of *social psychology*. From this point of view it is here considered.

There is no need to make the meter and kilogram the fundamental national standards of length and mass—that was done by executive sanction in 1893—nor to legalize the metric system so that all persons who choose may use it in their business—that was done by law in 1866. Two possibilities in further legislation present themselves: the one, to make the sanction of 1893 a congressional enactment and to provide for the exclusive use of the metric system in all departments of the national government, but leave the people to work their way toward the metric system at such time and in such manner as each individual may choose for himself (the plan in the bills recently before congress[13]); the other, to make it not only the exclusive system of the government but also the system which, after a fixed date, shall be obligatory in the commercial transactions of the people.

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[12]O. H. Tittmann, p. 7 of *Hearing before committee on coinage, weights, & measures, on H. R. 758*, Jan. 30, 1896.

[13]The Shafroth bill in requiring government use excepted "completing the survey of public lands." The last clause of the bill, "the weights and measures of the metric system shall be the legal standard weights and measures of and in the United States," would have no compulsive effect, and was intended to have none.

The author advocates the latter of these two plans and will attempt to show that it is both consonant with the most democratic ideas of government and accordant with sound views of "the social organism."

(*To be Continued.*)

Book Reviews.

Wild Birds in City Parks. By HERBERT EUGENE WALTER and ALICE HALL WALTER. 11.5×16.5 cm., 65 pages. Price 40 cents. A. W. Mumford, Publisher, Chicago. 1904.

The timely appearance of the third edition of this book is as spring-like as the season, and its new dress is as smart as the fine feathers of its subjects. The book is considerably enlarged by the description of fourteen additional land birds, some thirty shore and water birds, a glossary and a key for identifying the birds described. Indeed, though this is all valuable matter, the size of the present volume will make it a little less convenient for carrying. But the bird-lover will doubtless enlarge his pocket and thank authors and publishers for this little friend, grown-up.

We would suggest that, in the descriptive part, it would be an improvement to give the number of the birds whose name appears in black-faced type, so that comparison might be made without looking through the whole list. Also, in the "General Hints," reference numbers following the family characteristics would save time. For instance, if one observes "a tiny, tireless, gaily colored explorer of trees and shrubs," he must either look through the whole number of warblers described in the "Particular Hints" or trace his one special variety by means of the key. Lucky will he be if, by that time, the bird has not flown.

These are, however, minor defects in a unique and valuable little book. Though the authors modestly disclaim any surety in the key and warn against too great dependence upon it, it will certainly be very welcome to all bird amateurs.

E. F. M.

Reports of Meetings.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The thirty-seventh meeting was held in Boston, February 13, 1901. During the morning through the courtesy of Mr. Philip H. Wynne, formerly in charge of the equipment of the Boston Elevated Railway, the members inspected the power houses and equipment of the road, and witnessed a demonstration of the use of the accelerometer in railway engineering and in teaching the laws of motion. At the afternoon session, which was held at Simmons College, addresses were made by Vice-President George A. Cowen and Dr. Henry Le Favour, president of Simmons College.

Mr. Cowen's address was devoted to a consideration of the alleged decline of interest in physics in secondary schools. He said in part:

"Fifteen years ago at Phillips Academy, Andover, Professor Graves performed the experiments while the boys looked and wondered. Now they do and know. It is safe to say that in all New England at that time there was almost no laboratory work done by the pupil. With the change came the necessary demand for accurate measurement. But measurements of length and weight and force are of no use unless properly correlated. This is mathematics. Mathematics, it is affirmed, has made physics unpopular. Language without words would be about as sensible as physics without mathematics.

"In former days a boy was told that the piston of a steam engine was driven by the expansive force of steam, that the steam entered at one end, was cut off and allowed to enter the other, thereby causing the wheels to go. Such knowledge is good but is far from being a definite comprehension of the efficiency of the machine, nor does it give the boy any real estimate of the problems he must solve, if he is to put a better machine on the market. Today, thanks to the so-called Harvard Physics, mathematical if you please, the pupil knows some definite things about the expansion of gases, latent heat and thermo-dynamics.

"Next year the Massachusetts Institute of Technology will require physics for admission. It will demand a course not much dissimilar from Harvard's so that two different courses will not be necessary. More emphasis will be laid upon mechanics. A good laboratory course will be required. The only feature which this association might criticise is the absence of laboratory examination, which will remove a healthy stimulus. The new requirement will be a benefit to every secondary school. It will bring a class of boys to study the subject, that will be full of good workers. Experience seems to show that only fellows of more than average ability plan to take the four years of hard work that a diploma from the Institute demands. If the requirement call for a scientific and not a

cram course, if sufficient importance be placed upon laboratory work, the benefit will be far-reaching and lasting.

"Reference might be made to the complaint often made against Harvard for its failure to allow any credit for work in chemistry done in secondary schools, and to the way in which the Institute is trying to solve the problem of handling those who have had some chemistry and those who have had none.

"After all, the majority of our boys and girls do not go to college. Shall we give them the same course? Yes, but it should be longer and more comprehensive. A pupil wishing to pass off freshman work, might pursue such a course to advantage. If the boy can not study after the end of his high school course, he ought to be so equipped that if he should go into a shop or factory he would be head and shoulders above the fellows who gave up the fight four years earlier. It is the business of the high school to see that he is trained, if it is to be the college of the future. There is no doubt that the large schools are doing as much work in physics as some of the colleges were a few years ago. Where three years are given to the subject the last year can be devoted to very practical work. If a boy so trained should be employed by the General Electric Company he would be equipped for delicate electrical testing.

"At the present time the teacher of physics has remarkable advantages. Radium, mercury vapor lamps, flying machines, and many other things focus the minds of the young on their possibilities, if they but understand the subject. Interest in physics can not decline any more than interest in Russia and Japan can decline at the present crisis. Original work may be done by any teacher in his own laboratory. A pupil likes to feel that his teacher is progressive and resourceful. He easily detects the honest effort. Nothing could be a greater stimulus to pupils than to be allowed to help the teacher now and then. It is a delight to simply stand and hold the tape that binds the coil. While assistant in the laboratory at Williams College, it was my privilege to make some small pieces of apparatus. I believe now I really thought that I was a member of the faculty and it was the stimulus received there which determined my life work. The great advances along electrical lines in the next decade will be made with alternating current machinery. Watch the electrical magazines to see what some one else is doing and let that be a spur. Professor Pupin with mathematics, patience, and genius made it possible for the Bell Telephone Company to save $200,000 in copper, in one line alone, incidentally making the same sum himself.

"The New England Association of Chemistry Teachers has appointed a committee to arrange courses at Harvard or the Institute of Technology that shall meet the needs of the teachers of chemistry in greater Boston. It may seem wise for this Association to appoint a similar committee."

President Le Favour's address was informal and was devoted to the teaching of physics. After speaking of the advantages that physics offered as a subject for teaching, in that it combines data for abstract conceptions and finds illustrations and applications in the material of every day life, he considered the opportunities which the universites are offering in preparation for this work. The chief work of the physical departments of the universities is the training in mathematical physics or in experimental research. No fault can be found with this, for the advance of our knowledge must depend on both of these classes of scientists. The former test our new theories by their possible expression in mathematical form, and in so far as laws are simple, continuous, and universal, it ought to be possible to find such an expression. It is interesting to observe, however, that these expressions and the laws derived from them may be only ideal and not actually realized. It is certainly true that they can not be more than approximately verified by actual measurement. Even the simple expression for the law of gravitation varies so much from actual measurements as to make it possible that there is another term with higher powers of the variable. An interesting examination of the possible accuracy of physical postulates is found in Professor Ward's "Naturalism and Agnosticism." The training in experimental physics is undoubtedly of more value for teaching than that in mathematical physics; nevertheless it is not at all obvious that the qualities of mind that are best suited to overcoming the material difficulties of research are the same as those best suited to present the problems of physics to untrained minds. The really strong and successful teacher of physics, in the colleges at least, is very rare, and no effort is made to develop him. He must find his own way, and, as the speaker knew from his own experience, it is a very slow and uncertain way. After fifteen years of college teaching he found many difficulties unsolved. He believed very strongly in the use of a text book, illustrated and reënforced by informal lectures and discussions. Yet the colleges, with brief courses of one hundred hours, had no adequate text books. Their choice lay between books that were too elementary and those that were too compendious. The schools were more fortunate. The introduction of laboratory instruction had been of the greatest value, and the school men had done a very great deal to develop apparatus and methods.

Dr. Le Favour then considered physics in schools in its relation to the college course. It is always difficult to make proper use of this preparatory physics. The first difficulty lay in the very great diversity of the school courses, but even if this were overcome, the value of the preparation is of such a subtle character that the variation in the individual students adds to the difficulty. Aside from the accumulation of a rather small number of elementary facts, the preparation consists in giving to the student a point of view and some facility in quantitative judgment. In college the subject is begun anew, on a broader scale

with more difficult problems, and with more emphasis on the mathematical and philosophical phases. It differs in these respects from any other subject that is required in college. The speaker's experience at a college where no physics was required, and yet where a number of students did study the subject in school, led him to believe that those who had not studied the subject previously seemed to have about the same chance for success in the college work as the others. If this is generally true there is a waste of effort either in the methods used, or in the adaptation of the college course to the school course.

The following teachers were elected to membership:

Mr. Frank R. Clark, Woburn (Mass.) High School; Mr. George W. Low, Andover (Mass.) High School; Mr. Gaius B. Frost, Holliston (Mass.) High School; Mr. Charles Edward Fisher, Rhode Island Normal School; Mr. Homer W. LeSourd, Milton (Mass.) Academy; Mr. Nathan C. Hamblin, Tabor Academy, Marion, Mass.; Mr. Charles E. Dickerson, Mount Hermon School, Mt. Hermon, Mass.

The Association voted to send School Science to each member for the current year.

Reported by Lyman C. Newell.

CLEVELAND SECTION—CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

About two hundred reply postals were sent out early in February to the principals of secondary schools and deans of colleges within a radius of sixty miles of Cleveland, asking for the names and addresses of teachers of science and mathematics in such institutions.

Enough replies were received to furnish a mailing list of about three hundred names and the formation of a local center seemed justified by the interest shown.

Accordingly at a meeting of a committee composed of one representative from each of the five high schools in Cleveland and University School, the following program for a meeting was drawn up:

A meeting of Science and Mathematics Teachers of northeastern Ohio, held at Adelbert College and Case School of Applied Science, Cleveland, Ohio, Saturday, March 26, 1904.

PROGRAM.

9:00 a. m. (Standard Time)—Exhibit of Home-made Apparatus.

Informal Talk on Laboratory Equipment—Percy Hodge, Rayen School, Youngstown.

10:00 a. m.—General Meeting.

1. Address of Welcome—Professor F. P. Whitman, Adelbert College.

2. The Central Association of Science and Mathematics Teachers—Charles A. Marple, South High School, Cleveland.

3. Organization.

4. (*a*) Is it *desirable* to organize the subject matter of Algebra, Geometry and Physics into a thoroughly coherent four-years' course?—Elisha S. Loomis, West High School, Cleveland. (*b*) Is it *feasible?*—Principal George D. Pettee, University School, Cleveland.

1:00 p. m.—Lecture in Physics Lecture Room, Case School of Applied Science—"Radium and Radio-Activity"—Prof. Dayton C. Miller, Case School of Applied Science.

About seventy-five responded to the invitation to the meeting, representing some twenty-five different towns in northeastern Ohio, or about fifty schools.

After the meeting came to order Franklin T. Jones, of University School, Cleveland, was made temporary chairman, and Charles A. Marple, of South High School, Cleveland, temporary secretary. Following the discussion of the second number on the program, "The Central Association of Science and Mathematics Teachers," it was decided to organize a local center. A constitution was then adopted and the following officers chosen:

President, Franklin T. Jones, University School, Cleveland; vice-president, Miss Winona Hughes, Mansfield High School; secretary and treasurer; Clarence W. Sutton, Central High School, Cleveland; executive committee—Elisha S. Loomis, West High School, Cleveland; Prof. F. P. Whitman, Adelbert College, Cleveland; Prof. W. H. Wilson, Wooster University, Wooster; T. E. Crabbs, Greenville High School.; Charles A. Marple, South High School, Cleveland.

The officers of the local center are also *ex officio* members of the executive committee.

After the organization Mr. Elisha S. Loomis, of West High School, Cleveland, read a strong paper, giving many excellent reasons, drawn not only from theory, but from the facts as found in his long experience in teaching mathematics, why it *is* desirable that the subject matter of algebra, geometry and physics should be more closely correlated in the high school course than is at present the custom.

After luncheon at Case School, Prof. Dayton C. Miller, of that institution, gave a most interesting illustrated lecture in his lecture room on "Radium and Radio-Activity."

He showed by the electroscope, projected on the screen, how radium possesses the power of discharging electrified bodies—the gold leaves slowly moving together on the approach of the radium. Also by two or three samples of radium—one of considerable intensity—that it possesses the power of being self-luminous in the dark.

The great advance in the price of radium the lecturer attributed to the much advertised healing power of radium water—water exposed for

a time to radium rays—which is being exploited by sensational newspaper articles. Many physicians, while not believing in the therapeutic value, must perforce have a sample of radium, in order to be thought abreast of the times or "up with the procession," and were willing to invest $100 or more to secure one—and the price of radium has been about trebled.

The speaker thought it highly improbable, in fact ridiculous, that such water possessed any curative properties beyond that of any good water. One of the samples of radium shown was stated to be worth at the present market price more than $100, though it was secured some time ago for about $30.

Samples of the ore—pitchblende—from which the Curies have obtained the radium were also exhibited. At the close of the lecture a vote of thanks was tendered Adelbert College and Case School for courtesies shown and also to Professor Miller for his instructive lecture. The matter of affiliation with a state society of mathematics teachers, to be organized at Columbus, Ohio, the following Saturday was left to the discretion of the executive committee, two members from which committee were to attend the Columbus meeting and report.

The Cleveland center starts off with a membership of about forty and it hopes to have the good influences of the Central Association spread in this territory, and that later on a number of smaller centers may be established.

Reported by CHARLES A. MARPLE.

THE MICHIGAN SCHOOL MASTERS' CLUB.

The thirty-ninth annual meeting of the club was held at Ypsilanti, Mich., on Thursday, Friday and Saturday, March 31, April 1 and 2. On Friday evening occurred the dedication exercises of the new Science Building of the Normal College. Prof. John M. Coulter, of the University of Chicago, delivered the address, his subject being "Some Problems in Education Especially Relating to the Teaching of Science in Primary and Secondary Schools." He criticised the methods of teaching now in vogue, laying considerable stress upon the unfitness of many of those teachers who are endeavoring to teach science. He characterized nature study as the "joke of the scientific fraternity" on account of its so frequently falling into the hands of unprepared teachers. His address should be read by every superintendent and principal in the country, as it censured severely and not unjustly their methods in making programs, arranging courses of study, and choosing teachers for the science work of our schools.

After the address the Science Departments of Normal College held an informal reception in the new building, and gave their many friends an opportunity to inspect the excellent structure that the State has provided for this important work.

CONFERENCE OF PHYSICS AND CHEMISTRY.

The conference began its sessions on Thursday afternoon under the chairmanship of Mr. C. F. Adams, of Detroit. The first session was devoted entirely to questions of chemistry, the topics presented and discussed being as follows: "Chemical Change and Physical Change," by Dr. J. Montgomery, Ann Arbor High School; "Water Solutions and Water of Crystallization," by Mr. R. R. Putnam, Detroit Eastern High School; "Oxygen and Combustion," by Mr. L. A. McDermid, Owosso; "Hydrogen," by Mr. M. A. Cobb, Lansing; "Salt, Chlorine and Hydrochloric Acid," by Mr. W. L. Whitney, Saginaw; "Acids, Bases and Neutralization," by Mr. F. C. Irwin, Detroit Central High School; "Atmosphere, Nitrogen, Ammonia, Nitric Acid and Chile Saltpeter," by Mr. J. J. Marshall, Romeo; "Halogens (Periodic Law) Nitrogen Family," by Mr. L. Righter, Benton Harbor.

This programme was prepared by a committee appointed one year ago with Dr. Hulett, of Michigan University, as chairman. It was arranged with the idea of mapping out a line of work in preparatory chemistry on which all schools could unite and thus secure greater uniformity of work and methods in the schools of the State. A committee consisting of Dr. Hulett, of the University; Mr. Peet, of Normal College, and Mr. Irwin, of Detroit Central High School, was appointed to prepare a series of laboratory experiments to be presented at the meeting of the conference next year.

The second session of the conference was on Friday afternoon, at which Prof. E. A. Strong, of Normal College, exhibited a simple form of "Mach's Wave Apparatus." The performance of the device was excellent, and its plant was such that any teacher of very moderate mechanical skill could construct it. Professor Hulett gave a very interesting paper on the "Chemistry of Radium." It was expected that this paper would be followed by one on the "Physical Properties of Radium," by Prof. H. S. Carhart, but he was unavoidably absent to the great regret of the conference. The paper that provoked the most discussion was one by Dr. H. M. Randall on "The Relation of Mathematics to Physics in the High School." At the close of his paper the speaker raised the question whether it was not possible to improve on the present very unsatisfactory condition by bringing about some sort of an amalgamation of mathematics and physics, rather than by teaching them as now, as subjects wholly unrelated to each other. Several speakers referred to the inability of the average pupil to use his mathematics with accuracy and ease

in disposing of physical problems, but no one could present a remedy. The discussion was concluded by appointing a committee with Dr. Randall as chairman to take the question into consideration and present some scheme at the next meeting of the conference.

Prof. G. E. Marsh, of Adrian College, described an "Interrupter for a 500 Volt Circuit" that he had used successfully with an induction coil, obtaining a much longer spark from the coil than it had been designed to give and that without injury to it. Prof. N. F. Smith, of Olivet College, described a method of applying the micrometer caliper to measuring the elongation of a wire in determining Young's Modulus. His method was published in a recent issue of School Science. He also developed an ingenious method of applying the same instrument to the lever form of the apparatus often used in determining the coëfficient of linear expansion. It consisted in measuring the thickness of a thin sheet of metal inserted between the end of the rod and the short arm of the lever, noting the change of reading on the lever scale, and then calculating what thickness would be necessary to produce the change in the reading that was caused by the expansion, and thereby obtaining the expansion. Mr. H. N. Chute, of the Ann Arbor High School, exhibited an apparatus for obtaining the coëfficient of linear expansion in which the expansion of a metal tube was measured directly by the application of the micrometer caliper. Professor Smith also presented a very simple device for illustrating interference of light. Although not original with him, he excused himself for bringing the instrument to the attention of the conference on account of its simplicity and ease of manipulation. Two wooden bars of known length were hinged at one end, carrying near the hinge in slots, two plates of glass, set to exact parallelism and contact by being imbedded in plaster of Paris. The free ends of the bars carried a micrometer screw, which by its position and readings made it possible to calculate the angle formed by the glass plates. It was stated that good plate glass gave quite even interference fringes and yielded fair approximations in caluculating wave lengths when monochromatic light was used.

The third session of the conference was opened on Saturday afternoon by Mr. J. E. Fox, of Three Rivers, who exhibited an improvement on the well known method of obtaining the velocity of sound by means of a resonating air column. Water was admitted to a vertical glass tube from the bottom in the usual way. But the adjustment of the length of the column was accomplished by means of a pair of pinchcocks, one applied to the rubber tube delivering the water and the second to an outlet tube also entering the glass tube at the lower end. It was claimed that pupils experienced much less difficulty in obtaining an exact adjustment than by the old form. The conference was brought to a close by a business meeting at which Dr. H. M. Randall was

elected chairman for the ensuing year, Dr. Hulett, vice-chairman, and Prof. P. W. Peet, of Ypsilanti, secretary.

In connection with the meetings of the conference large and interesting exhibitions of apparatus, particularly for laboratory use, were given by Eberbach and Son, of Ann Arbor, and Stoelting and Company, of Chicago. The McIntosh Stereopticon Company, of Chicago, and Bausch and Lomb, of Rochester, N. Y., contributed very greatly to the interest of the conference by their excellent exhibits of optical apparatus.

Reported by H. N. C.

BIOLOGICAL CONFERENCE.

The meeting was called to order and announcements made by the chairman, Dr. George P. Burns, of the University of Michigan, after which, as the first number of the regular program, Dr. Burns read a paper entitled "Foundations for Successful Work in Plant Ecology." The main points emphasized were: A high school course in botany attempts more—the age and character of the pupils being considered—than a beginning course in the university. It may be called a university course at the opposite focus. . . . . The object of all botanical study is accurate observation, and the correlation and interpretation of facts gained. This can best be done in field work, since there apparatus and materials are always at hand. The difficulties of field work were discussed.

Some of the essentials in teaching ecology were named: First, a definite thing to see and study, and only cne thing at a time; second, the subjects to be considered in all field work—the topography, the soil, moisture and light. A record should be kept of all excursions made and of all plants studied. The teacher must know the names of plants commonly seen. The teacher must use, in field work, all the training acquired in the study of morphology and physiology.

Prof. C. C. Adams, of the University of Michigan, next spoke on "Development of Field Work in Animal Ecology." His ideas, in substance, follow:

For many years the zoölogical instruction in our high schools, normal schools and universities has been almost solely laboratory work. This method of instruction is admirable in many respects and is the only method for presenting certain aspects of the subject. And yet it ignores a most important part of zoölogy, the relation of the animal to its environment. This side of the subject is not only of great scientific importance, but also of the greatest popular interest.

From the present standpoint field zoölogy can not be properly taught witbort a certain, even considerable, amount of laboratory work. After

a certain amount of laboratory familiarity with the common forms more attention can be given in the field to the study of the activities of animals and the conditions under which they live. Beginners in field work must first learn a zoölogical alphabet—they must know the common forms at sight—before they can hope to read zoölogical sentences in the original. In other words, isolated, unrelated facts bear the same relation to scientific interpretation as isolated and unrelated letters and words do to a sentence. Field work should not aim merely at the acquisition of unrelated facts, but should seek for their interrelations and interpretation. To really read nature in the original the fundamental relations must be recognized.

The inadequacy of laboratory instruction alone is becoming more distinctly recognized each year. This is clearly shown by the constantly increasing demand for those who have a knowledge of field zoölogy. This demand extends all along the line from the teacher of elementary science to the college professor. It is coming to be clearly recognized that an essential qualification of the zoölogical instructor is a knowledge of animals in relation to their natural surroundings, a knowledge not based on the study of books alone, but resulting from a personal acquaintance with the field. Undoubtedly a very important factor in bringing about this change of opinion has been the rapid development of outdoor summer work. The advantages of the summer for biological study are very evident and are due to the great variety of material and the very favorable condition for field work.

It seems commonplace to remark that the animal habitats of a region are to a large degree determined by the local topography, and yet experience teaches that attention needs to be called to this fact. The different kinds of ponds, swamps, brooks, creeks and forested uplands are primarily expressions of this relation. What is there in common between different kinds of habitats? Is there some fundamental law at the bottom of all this? If so, it is bound to have great biological significance and we can not afford to ignore it in our field study. It is therefore necessary to learn the laws of blending and utilize them if we are to get at the fundamental laws controlling animal habitats. On such a basis only can we secure adequate methods of teaching field work.

One of the most important units for field work is the habitat. Since these habitats depend primarily upon the topography we must therefore learn in what way topographic changes affect habitat blending. By this means a natural sequence is found in which to study the habitats and their fauna. In this way we are led to the study of the origin of the various habitats and by this means at least one natural basis for field work is found. We are thus provided with a definite plan and method of attack. The primary difficulty with most field work is haziness of ideas as to what to do in the field. Mere collecting is not field study. Where collecting is the central idea field work often breaks down because the field excursion takes on the character of picnics. With definite

ideas regarding what to do in the field, and with equipment sufficient for individual work there is no room left for the "picnic" idea to develop.

Field Ecology is intended as an introduction to the study of the relation of animals to their natural environment, as illustrated by field work upon the local fauna. Special attention is given to the effect of the changing or dynamic aspect of the animal environment and its influence upon the fauna, or in other words, to the study of animal habitats and their fauna from a dynamic standpoint. The primary aim is not to give a mass of information, but to present a point of view, and such methods of work as should aid one in studying a local fauna. It is just such information as the isolated teacher most needs. The lectures and conferences outline the general principles and correlate the different kinds of work. The field trips are devoted to the study of the animals, the conditions under which they live, methods of observation, taking notes and collecting. Special attention is given to the observable dynamic conditions of the habitat and its effect upon the fauna. The laboratory hours are spent in the study and determination of the specimens collected, in the preparation of reports upon the field and laboratory work, and in securing a working knowledge of the important literature.

The discussion of Dr. Adams' paper was led by Prof. E. H. Harper, of Alma College, speaking briefly:

Field work is coming to be dominated by the ecological point of view. For the beginning student, however, the interest must be akin to that of the so-called "old fashioned naturalist" regardless of ecological generalizations. The distinctive interest of animal ecology to the beginner is in the observation of particular adaptations, whether of structure or of animal behavior, although from the point of view of the advancement of the science, questions of zoögeography are now attracting most attention. Witness the popular interest in the work of the zoölogical romancers upon animal behavior.

Besides the field excursion the school garden idea needs to be cultivated to bring the beginning student in all of his work into close observation of living forms. The "preserve" for the wild flora and fauna, a scheme carried out in a number of notable instances, is to be commended. We need a constructive policy in regard to the presrvation of our native species.

The third paper was by Mr. E. N. Transeau, of Ann Arbor, "Can Field Work Be Done Successfully in a Large City?" Mr. Transeau gave his own experience with a class in Chicago. These students were such miscellaneous types that holding them together depended on arousing their interest. He usually began with twenty trees or plants—giving the common names. In case of exotics the genus name was used. All these plants were studied as to characteristics of leaves, roots, stems, bark and manner of growth. In winter greenhouse plants were used; in spring

plant societies and their environment, in vacant lots adjoining the school building, were taken. Twenty-five trips of two hours each were made. Demonstrations of physiological processes were given in the class room to correlate the work.

Discussion followed by Mr. Kendall P. Brooks, of Marquette. Mr. Brooks said:

Difficulties in field work are of two kinds: First, difficulties with the pupils; second, those found in the field itself.

In regard to the first, the pupils must become interested in the work if it is to amount to anything. This is not hard to accomplish at the start. Last spring I found a good crop of mushrooms growing in my front yard; I made sure that they were of an edible variety and for the next field trip took the class to the house and gave them some, cooked in the proper way. The results were enough to fully repay me for my trouble; I had all kinds of mushrooms brought to me and the number of different varieties picked up by the class was wonderful.

If hours are arranged properly, there will be very little need of Saturday excursions. Those taken at the regular period will be much better attended by the pupils and more satisfactory in results.

If trips must be made on Saturday, permission to accompany the teacher will gain a larger party than a command.

Difficulties depending on the field appear greater, but are in reality less. It must be borne in mind that no two cities are alike and that each field must be studied for its own possibilities: An illustration: In Marquette snow is on the ground for five months of the school year. Field trips are taken in February on snowshoes; a study made of winter condition of trees; peculiarities of growth noticed in forest, in open, on lake shore, inland, in swamp, on hill; pines given particular attention, from both botanical and commercial point of view. A day was spent with a landlooker, by the teacher, and an attempt was made to make this part of the work very practical.

No city is without opportunity; teachers should use what is at hand; no two places are exactly alike, but there is not a place in Michigan where field work can not be done. If the teacher will only look around and recognize the possibilities of the situation and adapt himself and his work to the field, then field work will always succeed.

"The Value of Field and Herbarium Work in High School Biology," was the title of the next paper, given by Mr. W. T. Wallace, of Hastings.

For some time I have questioned the value to the average high school student of preparing an herbarium. Did the gains received equal the losses involved? Just what did this work accomplish for the student? Furthermore, I began to question my right as a botany teacher to send out classes of students for the purpose of procuring specimens, root and branch, thereby hastening the already too rapid disappearance of our native flora.

Then the doubt arose both as to the ability of ninth grade pupils to do this work and my ability to plan it, with the limited time at our disposal under present school conditions.

Still I could not let the question rest here. The aim of biological teaching is to put the student in the possession of accurate knowledge concerning plant and animal life, that through this knowledge as a medium he may come into fuller sympathy with the world about him.

To accomplish this end it is imperative that those methods of instruction be employed which shall insure such a result. To speak specifically, if plants are to be well understood by the student they must be known as organic wholes, related to each other and their surroundings as well as understood from physiological and anatomical standpoints.

It is self-evident that an ecological knowledge of plants can be satisfactorily acquired only by direct contact with plants as they grow and not until then will many of the facts learned in the laboratory be fully appreciated, while equally as important is the work of the laboratory that the varied ecological features may be understood.

In my judgment the value of good field work can not be emphasized too highly. Teach as well as we may in the class room in biological work, the fact remains that the world of which we teach is out of doors and the teaching which does not leave the pupil realizing this, fails in a most essential feature.

It is as an adjunct to such work as this in studying plant life that the herbarium may have a value as a means for emphasizing a condition or set of conditions.

Mr. William P. Holt, of Toledo (Ohio) High School, was to have discussed this paper, but not having seen it or an abstract of it he had prepared a paper along the lines of his own work. This paper he then presented, in part. It will be published entire in a future number of School Science.

The "Function of Nature Work in the Grades and What It Can Do for High School Biology," was the fifth and next topic, and was taken up by Miss Gertrude A. Gillmore, of the Washington Normal, of Detroit. The paper will be given in a later number of School Science.

Miss Mary A. Goddard, Michigan State Normal College, discussed the subject. She said in part: Miss Gillmore in her paper rightly attributes adverse criticism of Nature Study to faulty teaching. The cause of poor teaching is lack of knowledge or of a desire to gain knowledge.

Several ways may be given for extending the teacher's knowledge. First, go directly to nature. Carefully watch the daily lives of some plant or animal and learn what a child may see. Extend the observations, thereby coming to know nature first hand. Knowledge thus gained stays by one. Second, read reliable text, and other books. Send for the "Cornell Nature Study Leaflets," published by Humphrey, Geneva, N. Y.

Many valuable publications may be secured from State and United States Governments. The following are good: 1, Study of Plant Adaptations, Bull. 69, free, experiment station, Kingston, R. I.; 2, Structure of Corn Kernel (with fine illustrations), Bull. 87, free, experiment station, Urbana, Ill.; 3, Nature Study, free, experiment station, Pullman, Wash.; 4, Mosquitos and Fleas, Div. Ent., No. 13, Washington, D. C.; 5, Thirty Poisonous Plants, Farm Bulletin, No. 86, Washington, D. C. The remainder are from the Biological Survey, Washington, D. C. 6, Food of Bobolinks, etc., Bulletin 13, 5c; 7, Relation of Sparrows to Agriculture, Bull. 13, 10c; 8, Birds of the Maryland Farm; 9, Hawks and Owls from the Standpoint of the Farmer, Bull. 10, free; 10, The Blue Jay and Its Food, Bull. 66; 11, Bird Day in Schools, Bull. 17. Superintendent of Documents, Union building, Washington, D. C., will supply monthly and occasionally catalogues of all Government documents other than those of the agricultural department, while the section of agriculture, Washington, will give monthly lists of bulletins published by this department. Bulletin 247, Div. of Pub. Dep. Agriculture, gives a list of free documents. Third, cultivate the acquaintance of available persons who have long studied birds or trees, etc. Fourth, do not hesitate to consult college professors and instructors who will willingly render assistance.

The subject matter taught depends largely upon the locality and the teacher's knowledge. In many cases it is wise to study plant and animal life only. This is enough to open up the field of nature and create an interest in all her forms. Children should know the names of the plants in their vicinity, be able to tell when and how they come up and whether they need much or little sun and water. Every school should have a garden. Children should also know the names and habits of squirrels, birds and insects common in their locality. This work prepares them for the study in high schools of the physiological, chemical and physical principles which underlie all plant and animal activities. Dissection should not be practiced below the high school.

After a short business meeting the "Round Table" part of the program was called, but on account of the absence of two speakers and the lateness of the hour, the meeting adjourned. At the request of the secretary, Dr. Raymond Pearl, one of the round table speakers sent a letter on his views of "Nature Teaching." Part of the letter is here given by permission:

"One point which always strikes me forcibly when "field work" is up for discussion is this: The advocates of field work say that it greatly develops the young student's powers of observation to turn him into the "field" (by which I take it in ninety-nine cases out of a hundred they mean "all out-doors") and have him observe. Now it seems to me that this is about the poorest way to start training him to do close and accurate observing. Why? Because you give him *too much* to observe at once.

Nature is laid out on a very grand and lavish scale even in an acre lot. It takes a mature and trained person to pick out the essential from the mass and do close and accurate work in any kind of field work. The best example of this is found, I think, in the case of geology and physiography. My idea is that *before* a student is turned into field work he should have had thorough training in the laboratory and have been taught there, with objects with narrow and definite spatial limits, *how to do close observing.*. I can conceive of no better training in how to do close, careful, *truly scientific* observing than the kind of work Agassiz used to give his students in the laboratory. It seems to me then that so far as the aim of field work in high school biology is to furnish training for the powers of observation it goes wide of the mark in most cases, and must do so in the nature of the case. For this kind of discipline I believe nothing can equal the right kind of laboratory work. This view of the case is (or at least was), I believe, the underlying reason which led every educational institution which wanted to make true progress to introduce laboratory work in the sciences.

Now this would have been my text if I had spoken and you can see what a hornet's nest it would have stirred up, and what exceedingly unfit pabulum it is to serve to honest biology teachers with high ideals in that higher realm of cerebration labeled "The Nature Study Idea."

This may sound as if I disapproved of all work in the field. I hardly need say that nothing is further from my mind.

Reported by Louis Murbach, Secretary *pro tem.*